VOL. XLVI, NUMBER 4 WHOLE NUMBER 397

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR, C. A. CHANT ASSISTANT EDITOR, RUTH J. NORTHCOTT

David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS:

C. S. BEALS
Dominion Astronomer
Ottawa

R. M. PETRIE
Dominion Astrophysicist
Victoria, B.C.

A. THOMSON
Controller of the Meteorological Service of Canada, Toronto

PUBLISHED BI-MONTHLY
(Six numbers per year)

July-August, 1952

PRINTED FOR THE SOCIETY
TORONTO: 3 WILLCOCKS ST.

The Royal Astronomical Society of Canada

OFFICERS FOR 1952

NATIONAL OFFICERS AND COUNCIL

Honorary President—The Honourable W. J. Dunlop, Minister of Education for the Province of Ontario.
President—C. S. Beals, Ph.D., Ottawa.
First Vice-President—J. F. Heard, Ph.D., Toronto.
Second Vice-President—DeLisle Garneau, Montreal.
National Secretary—E. J. A. Kennedy, 3 Willcocks Street, Toronto.
National Treasurer—J. H. Horning, 3 Willcocks Street, Toronto.
Recorder—Frederic L. Troyer, Toronto.
Librarian—D. W. Best, D.D., Toronto.
Council—Charles A. Bell, B.A., Windsor; A. M. Crooker, Ph.D., Vancouver; Balfour W. Currie, Saskatoon; Charles A. Giroux, Quebec; Edgar Guimont, Montréal; G. Harper Hall, Montreal; E. S. Keeping, M.A., Edmonton; Rev. E. F. Maunsell, M.A., Hamilton; R. C. Moffatt, Guelph; Raymond E. Pearce, Toronto; E. H. Pope, Victoria, P. H. Serson, Ph.D., Ottawa; J. A. White, Winnipeg; R. E. Winters, London.

TORONTO CENTRE

Honorary President—C. A. Chant, Ph.D.
President—F. L. Troyer
First Vice-President—R. E. Williamson, Ph.D.
Second Vice-President—Raymond Pearce
Secretary—John Galt, 43 Adelaide St. E., Toronto.
Treasurer—T. H. Mason
Recorder—Miss Barbara Creeper
Council—C. A. Crook; David Gerrie; E. V. Greenwood; Mrs. K. M. Heaton; Helen S. Hogg, Ph.D., W. R. Hossack; A. Milne; A. Lloyd Morgan, M.D.; W. R. Sherrick; and *Past Presidents*—E. J. A. Kennedy; J. R. Collins; S. C. Brown; D. W. Best, D.D.; Miss Ruth J. Northcott, M.A.; J. F. Heard, Ph.D.; A. R. Clute, Q.C.

OTTAWA CENTRE

Honorary President—R. M. Stewart
President—D. A. MacLulich
First Vice-President—W. S. McClenahan
Second Vice-President—D. W. R. McKinley
Secretary—R. W. Tanner, Dominion Observatory, Ottawa.
Treasurer—Stanley Mott
Council—A. E. Covington; C. M. Cress; J. L. Locke; F. W. Matley; Miss Ethel D. Steacy.

HAMILTON CENTRE

Honorary President—W. T Goddard, B.S.E.E.
President—W. J. McCallion, M.A.
Vice-President—O. J. Paton
Curator—G. E. Campbell, M.A.
Secretary-Treasurer—George Murchie, 77 Fennel Avenue West, Hamilton.
Council—H. B. Fox; W. Jack; A. E. Johns, Ph.D., M. W. Johns, Ph.D.; L. O. Jones; Rev. E. F. Maunsell; W. S. Mallory, M.A.; T. M. Norton; F. Schnlider; F. Sisman; J. H. Sled, Phm.B.; W. J. Sled, B.A.; W. D. Stewart, B.A.; L. W. Welbourn; B. Wishart.

WINNIPEG CENTRE

Honorary President—L. T. S. Norris-Elye
President—D. R. P. Coats
Vice-President—Miss O. A. Armstrong
Treasurer—Miss M. E. Watterson
Secretary—
Council—Clarence L. Card; Allan Hill; V. Jones; H. E. Rasmussen; Fred Shanks; D. E. Sweeney.

VICTORIA CENTRE

Honorary President—Andrew McKellar, Ph.D.
President—Mrs. J. R. Noble
First Vice-President—Robert S. Evans
Second Vice-President—Edward H. Pope
Secretary-Treasurer—John L. D. Jervis, 1870 Cedarhill Crossroad, Victoria.
Recorder—Major E. R. Gibson
Director of Telescopes—Robert Peters
Council—S. H. Draper; D. P. McAlpine; N. G. Rogers; O. W. Smith; Miss Anne B. Underhill, Ph.D.; F. R. Williams.

MONTREAL CENTRE

Honorary President—G. Harper Hall
President—Miss I. K. Williamson
Honorary Vice-President—A. Norman Shaw, Ph.D.
Vice-President—D. E. Douglas, Ph.D.
Secretary—Henry F. Hall, 1441 Drummond Street, Montreal.
Recorder—E. E. Bridgen
Treasurer—C. N. S. Yarnell
Librarian—C. M. Good
Director of Observations—F. De Kinder
Council—Wm. H. Birtles; W. E. Leeson; Anna I. MacPherson, Ph.D.; A. R. McLennan; T. O. Plant; Paul Scott; R. O. Stevenson; R. Venor; W. J. Yorgan; Mrs. D. Zorgo and *Past President*—J. W. Duffie.

LONDON CENTRE

Honorary President—H. R. Kingston, Ph.D.
President—George W. Walden
Vice-President—W. G. Colgrove
Secretary-Treasurer—G. R. Magee, Ph.D.
Council—R. H. Cole, Ph.D.; E. Fanning; W. Gordon Graham; Omar Kilburn; E. E. O'Connor; and *Past President*—Albert Emsley.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XLVI, No. 4 JULY-AUGUST, 1952 WHOLE No. 397

THE JOINT AMERICAN ASTRONOMICAL SOCIETY–ASTRONOMICAL SOCIETY OF THE PACIFIC MEETING AT VICTORIA, B.C., JUNE 25–28, 1952

BY R. M. PETRIE

THE eighty-seventh meeting of the American Astronomical Society was held jointly with the summer meeting of the Astronomical Society of the Pacific at Victoria, British Columbia, June 25 to 28, 1952. This important event was a milestone in the history of the Dominion Astrophysical Observatory, since it was the first visit of the American Astronomical Society to Victoria and to western Canada. The meeting was most successful, both in attendance and in the number and calibre of the researches reported. The geographical location of Victoria undoubtedly reduced the number of astronomers attending from eastern Canada and the eastern United States, but this was compensated for by an extra large contingent from the south-west and the Pacific coast.

The main business of the meeting was, of course, the presentation of scientific papers. There were, however, two additional scientific events of special interest. On the evening of June 25th there was delivered the first *Robert Grant Aitken* Lecture. This lecture, established by the Astronomical Society of the Pacific in memory of the great double-star astronomer, was delivered by Dr. Robert R. McMath, director of the McMath-Hulbert Observatory of the University of Michigan. Dr. McMath chose as his subject "Solar Research at the McMath-Hulbert Observatory", describing a wide variety of current researches varying from detailed analyses of the infra-red spectrum of the sun to the photography of the spectacular prominences and surges and the measurement of their motions.* Professor Joel Stebbins introduced the speaker and delivered a tribute to the memory of Dr. Aitken.

On Thursday afternoon, June 26th, the societies, together with many representatives of the Victoria Centre of the Royal Astronomical Society

*The complete lecture will appear in an early issue of the *Publications of the Astronomical Society of the Pacific*.

Top: Dr. Joel Stebbins, Past President, A.A.S.; Dr. Robert R. McMath, President, A.A.S., 1952–54; Dr. R. M. Petrie, Dominion Astrophysicist.

Bottom: Dr. S. B. Nicholson, Past President, A.S.P.; Dr. Gerald E. Kron, President, A.S.P.; Dr. A. H. Joy, President, A.A.S., 1950–52; Dr. Otto Struve, Past President, A.A.S. and A.S.P.

of Canada, and the British Columbia Historical Society, met in the dome of the 73-inch telescope to witness the unveiling of a plaque in tribute to the late Dr. J. S. Plaskett. This tablet was placed upon the telescope by the Historic Sites and Monuments Board of Canada. The tablet was unveiled by Mrs. J. S. Plaskett, who spoke briefly of the devotion of her late husband to the Observatory and to astronomy. Dr. W. N. Sage, professor of History of the University of British Columbia, represented the Board, and Dr. J. A. Pearce delivered an address on the career and work of Dr. Plaskett. The services of this great astronomer to Canada and to our science were thus commemorated.

Mrs. John S. Plaskett and Professor W. N. Sage in front of tablet on the telescope pier.

Following the dedication the Observatory was host at a supper and open house. The telescope and the new stellar spectrograph, now attached to the telescope, were inspected by a large number of astronomers. A number of exhibits were arranged to show certain parts of the equipment and researches currently in progress. During the evening the visiting astronomers had ample opportunity to examine the laboratory, library, and the special instruments for spectroscopic analysis and to discuss with one another new astronomical problems. Unfortunately, cloudy skies prevented direct observations with the 73-inch telescope.

The contributed scientific papers, numbering 54, will not be described here, since abstracts of them will appear in the *Astronomical Journal* and in the *Publications of the Astronomical Society of the Pacific*. A wide field of interest was evident in the programme of titles, which ranged from theoretical and spectroscopic studies of the solar system to papers dealing with the new subject of radio astronomy. Nearly one third of the papers dealt with stellar spectroscopy in its various aspects. It is of interest to readers of this JOURNAL to record that eleven papers were presented by Canadian scientists from four different institutions.

A session of particular interest was held on June 26th, being a symposium in honour of Dr. Paul W. Merrill of the Mount Wilson and Palomar Observatories on the subject of "Emission-line Objects". The first paper, "Emission-line Objects of Early Type", was by Dr. C. S. Beals and Dr. J. A. Rottenberg, of the Dominion Observatory. The second paper, by Dr. Merrill himself, was entitled "Emission Lines in the Spectra of Long-period Variable Stars". The third paper was contributed by Dr. G. Herbig, of the Lick Observatory, on the subject "Emission-line Stars in Galactic Nebulosities". The symposium was a valuable part of the meeting, giving a survey of these important matters by authorities in their fields and presenting new results not yet available in the literature. The full text of these papers will appear in this JOURNAL.

Although the main business of the meetings was strictly scientific, the less austere side was not overlooked. During the visit at the Observatory a large body of scientists and their families made an excursion to the famous Butchart's sunken gardens. On Friday afternoon the ladies and other "non-professional" guests were taken on a comprehensive tour of Victoria and its environs. The main social event of the meeting was the official dinner at the Empress Hotel attended by nearly 150 persons. Presidents A. H. Joy (A. A. S.) and G. E. Kron (A. S. P.) represented their societies and Professor O. Struve acted as chairman, introducing the newly-elected President of the American Astronomical Society, Dr. R. R. McMath. The government of British Columbia also was represented. After dinner the guests were shown two films illustrating recent industrial developments at the Kitimat project and scenic views of Vancouver Island. The dinner brought to a close most of the official activities, and the guests left Victoria with many expressions of pleasure at the enjoyable and profitable sessions.

CELESTIAL EMISSION-LINE OBJECTS OF EARLY TYPE

By C. S. Beals and J. A. Rottenberg*

Introduction

The earliest record that we have been able to find of the observation of celestial emission-line spectra is the publication by Sir William Huggins[1] of his studies of the spectra of the nebulae. It is interesting indeed to read his account of this work which was done with a very modest slit spectrograph attached to an eight-inch reflector. The reader cannot help but share his astonishment and excitement at finding that the small, bright planetaries did not exhibit as he says "a spectrum" (i.e. a continuous spectrum) but only a series of monochromatic lines, the strongest of which was in the blue-green region. A number of observers were making studies of stellar and nebular spectra at about this time and in 1865 Secchi[2] observed the bright lines of the Orion nebula and makes reference to observations by Huggins of the emission-line spectra of the planetaries.

In 1866 the emission-line characteristics of another important type of emission-line object were discovered by Huggins[3] who was either the first or among the first to see the emission bands of a nova. The star concerned was T Coronae Borealis and Huggins found that the spectrum was characterized by emission lines due to hydrogen superimposed upon a continuous spectrum crossed by numerous dark lines.

Still another discovery of major importance to students of emission-line stars was made by Wolf and Rayet[4] at the Paris Observatory in 1867. Making use of a dispersing element consisting of a direct vision prism placed a short distance behind the focus of a reflecting telescope they detected the bright emission bands in three of the stars in Cygnus which have since been designated as Wolf-Rayet stars in honour of their discoverers. They also mention the bright-line character of the star γ Cassiopeiae and it may be assumed that they themselves had observed it although it may well be that, considering its brightness, others may also have studied its spectrum at about this time.

Thus within the brief space of three years all but one of the important groups of early-type emission-line spectra were discovered. Additional work along similar lines continued for the remainder of the 19th century and Keeler[5] gives a particularly interesting account of his own work on the nebulae by visual methods as well as that of earlier observers. A similar important investigation of the Wolf-Rayet stars by visual methods was made by Campbell[6] in the eighteen nineties.

*First paper presented at the symposium on "Emission-line Objects", American Astronomical Society meeting, Victoria, B.C., June 1952. Contributions from the Dominion Astrophysical Observatory, No. 27 (Part 1).

Probably the greatest step forward ever made in the history of astrophysics was the application of photography to the study of the heavens and one of the most important results of this application was the Henry Draper Catalogue of stellar spectra which was published early in the present century. This great work, which was based on objective-prism spectra, revealed the presence of great numbers of emission-line stars which had not been detected by visual methods. The new discoveries stimulated the detailed study of celestial emission-line spectra with powerful modern spectrographs at Ann Arbor, Cambridge, Mount Wilson and Victoria, as well as numerous other observatories in Europe and North America. Many of the results of these investigations have been summarized by Dr. P. W. Merrill and Miss Burwell[7] in their two well known catalogues of early-type emission-line stars which are a wonderful storehouse of scientific information including detailed references to earlier work. In addition to this invaluable compilation Dr. Merrill certainly ranks first among those who have made detailed studies of emission-line stars and the only reason he is not dealing with this aspect of the subject instead of ourselves is the fact that he has undertaken to deal with the more difficult subject of the nature of emission lines in late-type stars.

Types of Emission-line Objects

For the purpose of our present discussion celestial emission-line spectra of early type may be divided into the following classes:

1. Gaseous Nebulae; 2. Novae; 3. Wolf-Rayet Stars; 4. P Cygni Stars; 5. Be Stars.

Gaseous Nebulae. It is not intended to deal with the nebulae in any detail in this review which is devoted largely to the emission-line stars but the work of Hubble[8] and Zanstra[9] on the spectra of the nebulae is so intimately connected with later interpretations of emission in stars that it could not logically be omitted. Hubble showed that with a few possible exceptions the luminosity of bright diffuse nebulae was related to that of neighbouring stars and that nebular emission lines only appeared when the associated stars were of type B1 or earlier. This suggested that the emission nebulosity was excited by starlight and that emission lines of higher excitation would be found associated with very hot stars. These conclusions, when considered in connection with Wright's[10] observation of the high colour temperatures of the nuclei of planetaries, left little doubt of the general physical principle that emission lines in celestial spectra were excited in extended bodies of gas by hot stars.

The mathematical relationship between the temperature of the exciting star and the intensities of the nebular lines was developed by Zanstra. He showed that the only source of energy capable of producing the very great intensity relative to the continuous spectrum of the observed nebular

lines was the ultra-violet radiation from a very hot star of the order of 30,000° to 100,000°. The precise mechanism by means of which this energy might be transformed into monochromatic emission in the visible or ordinary photographic region may vary with the physical conditions in the nebula or with the particular atom involved. For hydrogen Zanstra assumed that the process was that of ionization and recombination—the quanta of ultra-violet starlight beyond the ionizing frequency being roughly equal in number to those which appear as observable emission lines in the process of capture. His well-known equation,

$$\int_{x_0}^{\infty} \frac{x^2}{e^x - 1}\, dx = \sum \frac{x^3}{e^x - 1} A_\nu$$

where $x = \frac{h\nu}{kt}$ and A_ν is an observed quantity depending on the strength of the line, may be used to derive the temperature of the nucleus of a planetary nebula.

For the so-called nebulium lines, which are really due to forbidden transitions in the spectrum of OIII, Zanstra assumed that electron impact was the means of transforming into visible radiation the energy absorbed in the process of photoelectric ionization. The corresponding equation,

$$\int_{x_0}^{\infty} \frac{x^3}{e^x - 1}\, dx - x_0 \int_{x_0}^{\infty} \frac{x^2}{e^x - 1}\, dx = \sum \frac{x^4}{e^x - 1} A_\nu$$

led to temperatures in reasonable agreement with those derived from hydrogen.

In other cases still more complicated exchanges of energy may be involved. An example is Bowen's[11] fluorescence mechanism by means of which a strong line of HeII at λ 303.78 excites a line of similar wave-length in the spectrum of OIII which in turn, after a series of electron transitions, excites a line in the spectrum of NIII of wave-length λ 374.44 A. The end result insofar as an astrophysically observable feature is concerned is the nitrogen pair at λ 4634-41 which is a conspicuous feature of many early-type emission-line spectra. The point worthy of emphasis in all these instances is that the original energy required to excite the emission lines comes from the absorption of ultra-violet starlight beyond the ionizing frequency of one or other of the atoms in the nebular shell of gases.

Novae. In modern interpretations of emission-line stars these ideas have been taken over with relatively little alteration. Beginning with novae the fact of the ejection of gases from the stellar surface and the formation of a gaseous shell around the star was established as long ago as 1904 by Halm.[12] Halm's ideas have been confirmed by more recent observations where the expansion of the gaseous shell has been observed directly. In addition to the evidence for the existence of a gaseous shell, the pro-

gressive increase in the excitation of the emission lines in the shell as the central star increases in temperature has been well shown by Petrie[13] and McKellar[14] as well as by other workers in this field. These observations left little doubt that the mechanism of excitation of the lines was essentially similar to that of the nebulae and that the energy of the tremendously intense emission bands arose as a result of the ionization of shell gases by the ultra-violet energy of the central star. The appearance of the nebulium lines and the enhanced nitrogen lines at λ 4634–41 gave further confirmation of the general similarity of the processes of line excitation in the nebulae and novae.

Wolf-Rayet Stars. Once the mechanism of excitation of emission lines had been established for the novae the application of similar physical principles to the interpretation of other emission-line spectra followed in logical order. For the Wolf-Rayet stars the widths of the emission bands (of the order of 3000 km./sec.) were comparable to those of the novae and it proved impossible to account for such widths on any other bases than the ejection of material from the stellar surface. The absorption borders on the violet edges of some of the bands provided further evidence of ejection. There was thus present an adequate mechanism for producing a gaseous envelope while the high temperature of the central star made available the necessary source of ultra-violet energy. The absence of the nebulium lines suggests, however, that the envelopes surrounding Wolf-Rayet stars are of greater density or of lesser extent than those associated with the novae.

P Cygni Stars. The P Cygni-type stars have narrower lines than those of the Wolf-Rayet objects but otherwise the similarities with the novae are even more marked. Not only P Cygni itself, the type star of the group, but also the star η Carinae, are old novae. Moreover the general character of P Cygni lines, of moderately broad emission with strong absorption borders on their violet edges is characteristic of the novae at certain stages of their development. No acceptable alternative has been put forward to replace the ejection hypothesis as an explanation of the very intense absorption borders which appear on the violet edges of the emission bands and it has accordingly been assumed that the emission lines of P Cygni stars have their origin in a shell of outward-moving atoms which is excited to luminosity by the light from a central star.

Be Stars. The Be stars, which include a few objects of classes O and A, are, for the most part, absorption-line stars in which a few emission lines make their appearance. The emission lines most commonly occurring are those of hydrogen, although wave-lengths due to helium, nitrogen, oxygen or ionized metals sometimes appear. There is no sharp distinction between Be and P Cygni stars and the P Cygni stars are included in Merrill and Burwell's lists of Be spectra. For the purpose of the present

discussion, however, the term Be is restricted to objects which do not show the P Cygni characteristic as a conspicuous feature. The most characteristic feature of a Be star as described by Merrill is the appearance of emission lines of hydrogen superimposed on broad absorption. The emission lines are frequently cut by narrow central absorption and these double emission lines, the two components of which frequently show unequal or variable intensities, have come to be regarded as the most definitive aspect of Be spectra.

By analogy with other emission-line objects already mentioned it may reasonably be supposed that Be emission lines have their origin in an extensive envelope of gases surrounding the star. Evidence confirming this idea has been derived from eclipsing stars when the eclipse of a stellar disk has revealed the presence of an emitting envelope of considerably greater diameter than the central star.[14a] The most probable origin of such an envelope is to be found in the ejection of atoms from the stellar surface even though there is usually no direct evidence of the kind found in the spectra of the novae, Wolf-Rayet and P Cygni stars. In this connection it may be pointed out that even in a low-temperature star like the sun there are many phenomena that point to a fairly large scale ejection of atoms from its surface and that quite apart from any other evidence it might be expected that such ejection phenomena would be more important for stars of higher surface temperature. It is probable therefore that ejection of atoms is a feature of all early-type stars and that when this process assumes major proportions a star of sufficiently high temperature will show emission lines.

Analytic Interpretation of Emission-line Profiles

There is as yet no well-trod approach to the quantitive interpretation of bright-line spectra; none, that is to say comparable to that which has evolved for discussing a "normal" stellar spectrum.

The above survey cannot have failed to show that there does exist a unified viewpoint from which the emission-line objects can be scanned, namely, the presence of a hot star surrounded by a large diffuse envelope in motion. It has been an inductive argument. Scientific method requires that the reasoning now be reversed and that one attempt to regain the particular from the general. Without introducing any sensibly new assumptions, then, we are obliged to outline a method of deriving profiles from one common model; the method to be such that, when the calculations are actually carried out, the resulting profiles reproduce those by which this group of objects is identified.

Consider, for a moment, the problem of deriving the profiles that can be produced by an envelope, simply as a consequence of its optical depth at the line frequency and because of its motions and dimensions. It is to

have no sources of radiation within itself. The spectrum at the base of the envelope may be supposed known; the spectrum outside is to be determined. One method of effecting this would be to follow the changes in the flux with height, from the inner to the outer boundary. (By the outer boundary one means that height at which one can say the radiation escapes without change.) This procedure requires a much more detailed knowledge of the run of physical variables than we have at hand. Also it involves the solution of a highly complicated equation of transfer. As the published work[15, 16] in which this approach is taken makes clear, it is a rather forbidding line of attack.

Another method is, however, available. The extent of the envelope and the various motions within it can be analysed in terms of the effect that they have on the rate of absorption from and emission into a single ray. If then the optical depth at line centre, the radii of star and envelope and the more important velocity components are adopted as parameters (ultimately to be determined by observation) the total of all rays which enter into the radiative equilibrium of the envelope can be mathematically expressed and the corresponding profile derived. This does not give a complete account of the internal state of the envelope but none-the-less it produces contours which agree well with the ones observed and which allow gross estimates of the envelope's form to be made.

In a first treatment, the large-scale motions of the atmosphere or envelope may be resolved into a velocity perpendicular and a velocity parallel to the stellar surface. As the archetype of radial motion one can think of an expanding atmosphere; of transverse motion, a rotating atmosphere. At some later stage the two general types of atmosphere-in-motion can be compounded.

It has been found that, for purposes of analysing the radiative process, a further resolution of the motion takes place. One component is provided by the directed velocity, v (radial in the case of expansion, transverse in the case of rotation). The other, v^*, is due to those motions for which no common direction can be specified. These can be traced to thermal velocity v_0, turbulence v_T and velocity gradients v_g in the atmosphere. Considered as truly random velocities they give a "mean random motion",

$$v^* = \sqrt{v_0^2 + v_T^2 + v_g^2},$$

whose effect is solely to broaden the absorption or scattering cross-section. They produce a form of non-coherent scattering. The directed or uniform velocity makes its presence known when radiation passes from one part of the envelope to another or from the star to the envelope. Its manner of entry is contained in the familiar Doppler formula,

$$\nu' = \nu\,[1 + (v/c)\cos\theta].$$

The ratio v/v^* of the directed to the random velocity is found to play a critical role in determining the type of emission profile that is produced.†

In addition to being the source of the envelope's radiation the star is also an absorber of it. In the cases of which we must treat, it is not generally permissible to assume that the star is a dimensionless point with respect to the size of its envelope. In this and in the Doppler shift under self-illumination, the description of the energy flux departs from the pattern first laid out by E. A. Milne[17] for treating the radiation field falling on a planetary nebula.

With these considerations taken care of (namely, the finite size of the star, the self-illumination and the effect of non-uniform velocities) the radiative equilibrium of the envelope can be given mathematical expression.

A relatively detailed account of the theory of emission-line profiles and the methods of calculation has been published elsewhere.[18] Here we will content ourselves with discussing some of the results of the calculations and their relation to observed emission lines.

Computed Profiles

1. *Pure Emission (transparent envelope).* The cases of this type which have importance in application are of course those in which the contour has been broadened by the envelope's motions so as to form a band. If the velocity of expansion—or contraction—far exceeds the non-uniform velocities, the band will be flat-topped (figure 1). The slope of the sides gives the dispersion in velocities.[19] (Such profiles are not often observed.)

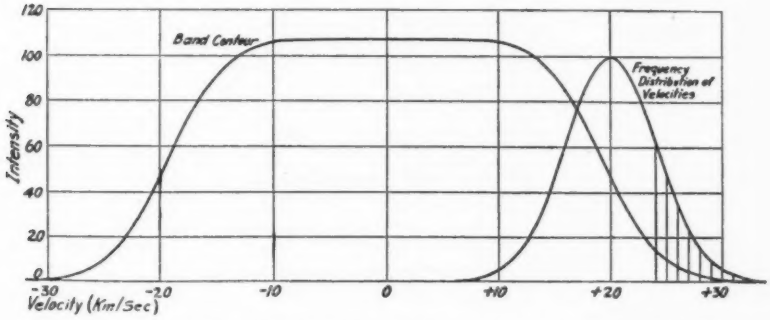


Fig. 1.—The contour produced by pure emission. (Point star) The envelope has a velocity of expansion of 20 km./sec. and a spread in velocities of about 14 km./sec.

†It should be noted that substantially the same ratio enters the discussion of radiation *pressure* in envelopes and in planetary nebulae. We find from the profiles the same order of magnitude for this factor as was inferred by Amberzumian, Chandrasekhar, Zanstra *et alia* from the dynamics.

Otherwise the bands have rounded tops. From the correlation of band width and ionization potential it is often possible to infer both stratification of the envelope and the presence of a velocity gradient.

Calculations to show occultation effects at the red edge of the band have been carried out and suggest it should be observable.[20]

These calculations took account of possible positive or negative velocity gradients but not of turbulence or thermal motions and they would probably have to be extended in order to be applicable to estimations of relative sizes of star and envelope.

Exactly the same profiles result when the motion of the envelope is that of a rotation. On physical grounds, of course, rotational velocities cannot reach the magnitude of the large velocities of expansion observed in Wolf-Rayet stars and novae, and so the chances of actually observing a flat-topped band are much less.

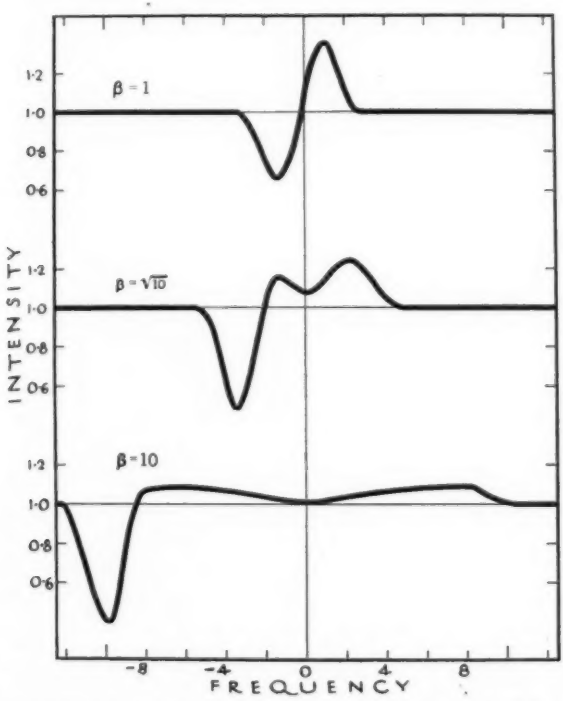


FIG. 2.—The contours produced by pure scattering and radial motion of the envelope. I. (Point star). β is the ratio of the expansion-velocty to the mean random velocity, (v/v^*). The unit of frequency is the Doppler shift produced by a velocity v^*. (The optical depth of the envelope at the central frequency is 1.)

2. *A Semi-transparent Envelope in which the Predominant Motion is Radial.* A rather surprising result turns up here. When an envelope is the source of its own radiation (the case of pure emission) the bright-line profile remains single, no matter what the velocity distribution, provided it is radially or rotationally symmetric. Application of the theory shows that in a pure scattering envelope (where the mechanism of ionization and combination is not operative), the motion of expansion will result in a redistribution of energy in the line. This will show up as a combination of emission and absorption components and may result in a doubling of the line. The illustrated profiles show how this depends on the ratio β, of the expansion velocity to the random velocities (figure 2). Notice that it requires a relatively large random velocity, roughly a third of the velocity of expansion. These profiles are often seen in P Cygni-type spectra and

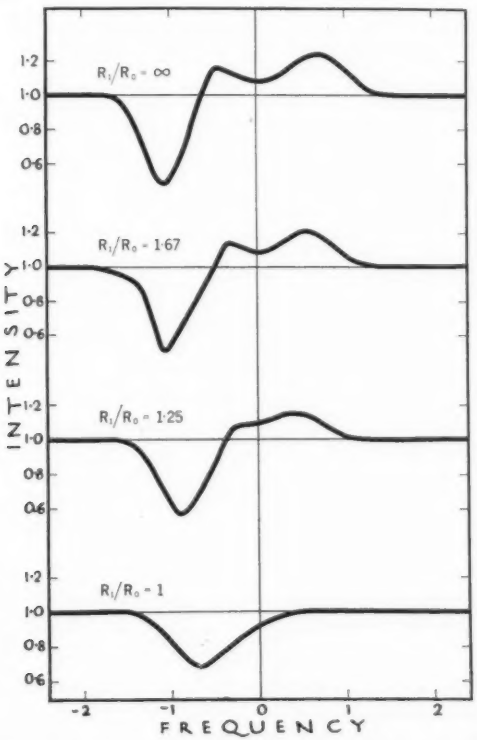


FIG. 3.—The contours produced by pure scattering and radial motion of the envelope. II. ($\beta = \sqrt{10}$). R_0 is the radius of the star; R_1 is the mean radius of the envelope. (The optical depth of the envelope at the central frequency is 1.)

imply that either the velocity gradient or the turbulence is considerable. More than likely it is turbulence.

The consequences of occultation can be traced with the same model, as one lets the size of the envelope shrink (figure 3). The limiting case will be recognized by at least two members of the audience,[21, 22] as the profile they derived from the theory of plane-parallel atmospheres.

The important conclusion here is that one cannot read the ratio of the two radii (stellar and atmospheric) from the emission components alone. A better test, if the continuum were well located, would be the *maximum* velocities in absorption (violet) and in emission (red).

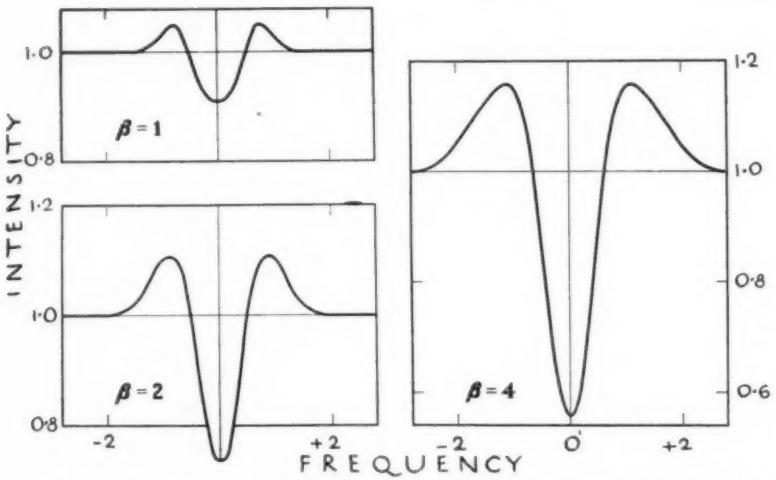


FIG. 4.—The contours produced by pure scattering and transverse motion of the envelope. I. (Point star) β is the ratio of the rational velocity to the mean random velocity, ($R\omega \sin a/v^{\circ}$). The unit of frequency is the Doppler shift produced by a velocity v°. (The optical depth of the envelope at the central frequency is 1.)

3. *A Semi-transparent Envelope in which the Predominant Motion is Transverse.* The profiles in this group were obtained from a model which consisted of an envelope in radiative equilibrium with a small black-body about which it rotates (figure 4). The sharpness of the core depends on the ratio,

$$\frac{R\ \omega \sin a}{\sqrt{v_o^2 + v_T^2 + v_g^2}},$$

of the projected velocity of rotation, $R\ \omega \sin a$, to the resultant of the non-uniform velocities, $\sqrt{v_o^2 + v_T^2 + v_g^2}$, where R is the effective radius of the envelope, ω its angular velocity, a the inclination of its axis, v_θ is the

thermal velocity, v_T the turbulent velocity, and v_g the velocity gradient. The core naturally disappears when there is no rotation across the line of sight.

The profiles for this model are much more sensitive to the size of the envelope than is the case in the preceding one, where the motion was radial. If the radius of the envelope is not almost twice that of the black-body, the profile is not noticeably different from the limiting case of equal radii. The limiting contour is shown in the right-hand profile of figure 5. When the radius of star and envelope are equal, the model coincides with the one on the basis of which Struve[23] obtained the profile of a rotationally-broadened absorption line. So it is not surprising that this profile agrees with his.

The profile on the left of figure 5 is the result of a calculation in which the rotating envelope was again much larger than the enclosed black-body, the optical depth at line-centre having been raised to $\tau = 3$. In the preceding cases the depth was $\tau = 1$.

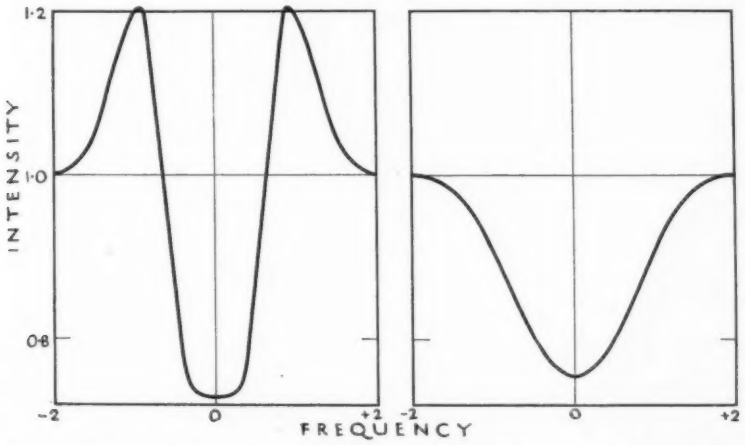


FIG. 5.—The contours produced by pure scattering and transverse motion of the envelope. II. The profile on the left is that of a point star, enclosed by an envelope whose optical depth at the central frequency is 3 (cf. the second profile of figure 4). The profile on the right is that of a star enclosed by an envelope of the same radius as the star.

4. *Envelopes Consisting of Two Shells.* Models have also been considered in which the envelope, although sufficiently ionized to emit according to the Zanstra cycle, also manages to present an appreciable opacity to the escape of photons of line-frequency. Space does not permit a discussion of these here. Accounts of the calculation and the resultant

profiles are published elsewhere, others are being prepared for publication. One can anticipate the form the profiles take by thinking of the contours of the preceding two sub-headings as modulating a broad emission band.

The Temperature of Emission-line Stars

If it be assumed that the process of ionization and recombination is the principal mechanism responsible for the excitation of stellar emission lines it is possible to derive the temperatures of individual objects from Zanstra's equation and to draw up a scale of stellar temperatures based on emission lines alone. There are certain valid objections to the application of this method to all atoms, one of which is the existence of Bowen's mechanism of fluorescence. It appears probable, however, that if main reliance is placed on the atoms of H, HeI and HeII that the results will be of the correct order of magnitude. A temperature scale built

TABLE I

Temperature Scale
Early-type Stars

Class	Temperature ° K		
	Absorption Lines and Continuous Spectrum	Emission Lines	Adopted
Planetary Nebulae		140,000 to 30,000	140,000 to 30,000
W5		110,000	110,000
W8		50,000	50,000
O5	36,300	40,000	38,000
O9	30,700	34,000	32,000
B0	25,000	32,500	28,000
B9	13,500	17,000	15,000
A0	14,000	16,000	14,000
A4	11,000	11,000	11,000

up in this way is shown in Table I. Here Zanstra's temperatures are used for the Wolf-Rayet stars and values derived by Beals and Hatcher are used for the P Cygni stars which cover the O, B and early A classes. For purposes of comparison the table also includes ionization temperatures

derived by Petrie for the absorption O's and the colour temperatures of the B's and early A's by the Greenwich observers. The agreement on the whole is very good and suggests that we now have for the early-type stars as a whole a temperature scale in which we may have reasonable confidence.

The high temperatures indicated for the planetary nebulae and the Wolf-Rayet stars are a conspicuous feature of the table. A study of general classification and temperature data reveals an additional interesting fact, namely that there is a lack of absorption-line stars definitely known to be of earlier spectral type than O5. That is not to say that none exist but they are at least not common in the magnitude ranges ordinarily studied by astronomers. This fact may be explained by supposing that for temperatures above about 50,000° the normal stellar spectrum is of emission type just as for lower temperatures the normal spectrum is of absorption-line character.

On this basis the Wolf-Rayet stars and a majority of the planetary nebulae would represent an extension to earlier spectral types of the normal Harvard sequence of absorption-line stars. Such an hypothesis does not, of itself, offer a solution to the many physical problems which these interesting objects present. It does, however, suggest a new point of departure for the study of such problems. As has already been mentioned the ejection process provides a means for producing a Wolf-Rayet envelope and the same process on a more limited scale is probably involved in the envelopes of all emission-line stars. The symmetrical character of the envelopes of planetary nuclei suggests ejection from the nucleus as the most probable origin and the fact that some nuclei are of Wolf-Rayet character gives further credence to such an idea. It may be, therefore, that high surface temperature alone is sufficient to produce an emission-line object such as a Wolf-Rayet star or a planetary nebula and that the distinction between the two may depend upon the relationship between temperature and surface gravity or other physical parameters not now fully understood.

These various possibilities require more detailed investigation and it is hoped that the profile theory outlined here, which gives some insight into the dimensions and types of motion of the emitting envelope, together with the method of model atmospheres which should help in defining the physical conditions at the base of the envelope, may eventually lead to a clearer understanding of the physical nature of these interesting early-type stars.

REFERENCES

[1]*Phil. Trans. Roy. Soc.*, 1864.
[2]*Comptes Rendus*, vol. 60, p. 543, 1865.
[3]*Proc. Roy. Soc.*, vol. 15, p. 146, 1866.

[4]*Comptes Rendus*, vol. 65, p. 292, 1867.
[5]*Pub. Lick O.*, vol. 3, p. 165, 1894.
[6]*Astronomy and Geophysics*, vol. 13, p. 448, 1894.
[7]*Ap. J.*, vol. 78, p. 87, 1933; vol. 98, p. 153, 1943.
[8]*Ap. J.*, vol. 56, p. 162, 1922.
[9]*Ap. J.*, vol. 65, p. 50, 1927; *Pub. D.A.O.*, vol. 4, p. 209, 1930.
[10]*Pub. Lick O.*, vol. 13, p. 248, 1918.
[11]*Ap. J.*, vol. 81, p. 1, 1935.
[12]*Proc. Roy. Soc. Edin.*, vol. 25, p. 513, 1904.
[13]*Pub. D.A.O.*, vol. 6, p. 338, 1937.
[14]*Pub. D.A.O.*, vol. 6, p. 347, 1937.
[14a]*P.A.S.P.*, vol. 59, p. 562, 1949.
[15]W. H. McCrea and K. K. Mitra, *Zeits. f. Astroph.*, vol. 11, p. 359, 1936.
[16]S. Chandrasekhar, *Rev. Mod. Phys.*, vol. 17, p. 138, 1945; *Ap. J.*, vol. 102, p. 402, 1945.
[17]*Zeits. f. Astroph.*, vol. 1, p. 98, 1930.
[18]*M.N., R.A.S.* (in press).
[19]C. S. Beals, *Pub. D.A.O.*, vol. 6, p. 113, 1937.
[20]S. Chandrasekhar, *M.N., R.A.S.*, vol. 94, p. 522, 1934.
[21]O. C. Wilson, *Ap. J.*, vol. 82, p. 733, 1935.
[22]A. B. Underhill, *Ap. J.*, vol. 106, p. 129, 1947.
[23]*M.N., R.A.S.*, vol. 89, p. 222, 1929; *Pop. Ast.*, vol. 53, p. 201, 1945.
[24]*Cont. D.O.*, vol. 2, p. 1, 1948.
[25]*Pub. D.A.O.*, vol. 7, p. 334, 1947.

COMMUNICATIONS
FROM THE
DAVID DUNLAP OBSERVATORY
UNIVERSITY OF TORONTO
Number 30

THE FREQUENCY AND CHARACTERISTICS OF BINARY SYSTEMS AMONG BRIGHT-LINE B-TYPE STARS*

By R. F. Rodgers

Introduction

This paper concerns a comparison of the properties of Be-type stars with those of B-type stars. Two such properties have been dealt with in some considerable detail by other investigators. These are:

(1) *Luminosity.* Wilson[1] has shown that the absolute magnitude (intrinsic luminosity) of Be-type stars is about the same as B-type stars. This equality of luminosity also applies to the c-stars, according to Seyfert and Popper.[2]

(2) *Rotation.* In many papers Struve has pointed to evidence for believing that the Be-type stars are the fastest rotating of the B-type stars and recently Slettebak[3] has made an analysis of the breadth of lines in the spectra of a number of stars to confirm this view. Those stars classified as Bn are regarded as rotating rapidly and those classified as Bne as rotating still more rapidly. Those which have sharp-line (s) spectra are either quickly-rotating and have their axes of rotation directed toward the earth, or are slowly-rotating. Bse-type stars are all quickly-rotating, whereas Bs-type stars include both quickly- and slowly-rotating stars. This difference of rotation is one of the chief reasons why a Be-type star is an emission star, since the great centrifugal force of rotation dilates the star's atmosphere, and this extended atmosphere is the source of emission.

Two other properties which are discussed in the present paper are:

(3) *Mass.* One might expect the masses of the Be-type stars to be of the same order as those of the B-type since their luminosities are equal. In the course of the present investigation the periods of ten established Be-type spectroscopic binaries were plotted against spectral subclass and compared with a similar plot for 134 B-type spectroscopic binaries, the

*Summary of a thesis submitted in partial fulfilment of the requirements for the degree of Master of Arts in the University of Toronto, June 1952.

data being taken from Moore and Neubauer's fifth catalogue of spectroscopic binaries.[4] There was no systematic trend to indicate differences of mass between Be- and B-type stars.

(4) *Incidence of Binaries.* It is with the question of the relative incidence of binaries among Be-type stars and B-type stars that this investigation is chiefly concerned. It will be shown below that the incidence of binary systems among Be- and B-type stars appears to be related to the rapidity of rotation. This relationship will have a bearing on theories of stellar evolution.

The data for the present investigation were taken largely from the following sources: Merrill and Burwell's catalogue of Be and Ae stars[5] and supplements,[6, 7] Aitken's double star catalogue,[8] Kukarkin and Parenago's general catalogue of variable stars,[9] and Plaskett and Pearce's catalogue of radial velocities of O- and B-type stars.[10]

Be- and B-type Binary Systems

Struve[11] has noticed that Be stars seem to have a lower incidence of spectroscopic binaries than B stars. This could be caused by observational selection factors, such as inability to demonstrate that a given Be star has variable velocity, owing to the poor character of the nebulous-line spectrum and consequent uncertainty in radial velocity (Be stars are noted for the poor quality of their spectra). It was the main purpose of this investigation to discover if this seemingly lower incidence of Be spectroscopic binaries is real and also to inquire as to the relative incidence of visual binary systems and eclipsing binary systems among B and Be stars.

If we know the total number of B binaries, and also the proportion of Be stars among the B stars, then we may calculate the total number of Be binaries, assuming that the incidence of binaries is the same among stars of both classes. By comparing this computed number of Be binaries with the actual number of Be binaries, we may decide whether the incidence of binaries is the same in the two groups of stars, and, if not, in which group it is the greater. By investigating eclipsing and visual binary systems in this way, it was found that, of 113 B eclipsing binaries, seven Be binaries were predicted, whereas eight were observed; and of 847 visual binaries which are of type B, 493 were bright enough for a valid analysis, and of these the number of Be binaries predicted was 25, and 25 were observed. From these figures it was concluded that the incidence of eclipsing and visual binaries among Be stars is the same as among B stars. The result was strengthened by the fact that the proportion of velocity variables, without consideration of the character of the spectra, among 96 Be and a corresponding number of B stars was found to be the same. Hence

the total incidence of binaries among Be stars as a whole may be taken as being the same as the incidence among B stars.

In order to use to best advantage the data referring to spectroscopic binaries, an analysis of the published radial velocities must be made, since many spectroscopic binaries lack orbit determinations. It is necessary to take into consideration the character of the stellar spectra, since a nebulous-line spectrum gives a velocity of low weight, whereas a sharp-line spectrum gives a good velocity. For this reason nebulous-line spectra were treated together. If it is assumed that a binary star's equator is nearly parallel to its orbital plane, it follows that, for these nebulous line stars, the observed velocity amplitude is very nearly as great as the maximum velocity amplitude, and hence easy to detect.

Four methods of analysis were tried; each method gave a smaller incidence of binaries among Bne stars than among Bn stars. The significance of this result is discussed below. Of the methods used, one, which is a simplification of that used by Heard,[12] is the best. The principle of this method of analysis is reviewed briefly in the following paragraph.

We assume, to begin with, that all lines on a given spectrogram of a given star should yield the same velocity. That is, we exclude groups of stars for which it is known that different lines yield systematically different velocities. Then the variations of the velocities from individual lines are due to errors in measurement, and a quantity expressing this variation, called the variance, may be estimated. Also from the spectrogram-to-spectrogram velocity variations another variance may be obtained. The ratio of these two variances, combined with the number of lines and the number of spectrograms involved, gives a measure of the probability that some real variation exists in the measured velocities of the given star, as opposed to variations arising only from errors of measurement.

This method of analysis was applied to all Bne stars found in the Victoria catalogue and in the Publications of the David Dunlap Observatory, amounting in all to 71 stars. These stars were put into groups according to spectroscopic subclass and their velocity variations were compared with those of similar groups of Bn stars. In this way it was found that the incidence of velocity variables is less for the Bne stars than for the Bn stars by a ratio of about 2 to 3.

Now many Be stars show variations of velocity which cannot be explained by simple binary motions. This is illustrated by two stars observed here during the past season. One of these, H.D. 12302 (M.W.C. 23), was found to have a variable velocity with about a 3000-day cycle; these variations cannot be reconciled with simple orbital motion because the cycle does not repeat itself exactly. The other, H.D. 180398 (M.W.C. 312), has a period of 5.4011 days, but again, the variations cannot be explained by simple orbital motion since different lines show different velocity varia-

tions. Therefore we may say that the ratio of the incidence of spectroscopic binaries among Bne compared with Bn stars is *less* than 2 to 3.

It has already been shown that the incidence of binaries among Be stars is the same as among B stars when we include sharp-line stars as well as nebulous-line stars. The most reasonable way of reconciling this result with that of the preceding paragraph is to conclude that the incidence of binaries among Bs stars is very small.

Thus we have adduced evidence indicating that the incidence of binaries is related to rotation; for moderately rotating stars, the incidence is a maximum, and it becomes less for very rapidly rotating and also for slowly rotating stars.

While the exact course of the evolution of these stars is not known, and while this analysis leaves the problem still unsolved, it is interesting to speculate about a possible course of development which is consistent with these results. Let us suppose that a B star is rotating so rapidly that it is on the point of breaking up. This star would be a single Be star. If it then breaks into two stars, both rapidly rotating, the system would be a Be binary. Changes could come about which would reduce the rotational speed slightly, the stars would lose their emission, and they would form a Bn binary system. Hence the class of moderately rotating B stars would accumulate former Be binaries. The Bs stars would always have few binaries because they would not be rotating fast enough to split up.

The author would like to thank the observers at this Observatory who took the spectrograms for him and Dr. B. A. Griffith of the University of Toronto and Dr. W. W. Morgan of the Yerkes Observatory for valuable suggestions. He would like especially to thank Dr. J. F. Heard, who suggested and supervised this investigation.

References

[1]*Ap. J.*, vol. 94, p. 12, 1941.
[2]*Ap. J.*, vol. 93, p. 461, 1941.
[3]*Ap. J.*, vol. 110, p. 498, 1949.
[4]*L.O.B.*, vol. 20, p. 1, 1949.
[5]*Ap. J.*, vol. 78, p. 87, 1933.
[6]*Ap. J.*, vol. 98, p. 153, 1943.
[7]*Ap. J.*, vol. 110, p. 187, 1949 and vol. 111, p. 666, 1950.
[8]"New General Catalogue of Double Stars." Washington, Carnegie Institution, 1932.
[9]"Obschii Katalog." Leningrad and Moscow, Akademia Nauk S.S.S.R., 1948.
[10]*Pub. D.A.O.*, vol. 5, p. 99, 1931.
[11]"Stellar Evolution." Princeton, Princeton University Press, p. 194, 1950.
[12]*Ap. J.*, vol. 109, p. 185, 1949.

David Dunlap Observatory,
Richmond Hill, Ontario,
June 1952.

VARIABLE STAR NOTES

American Association of Variable Star Observers

By MARGARET W. MAYALL, *Recorder*

THE officers and members of the A.A.V.S.O. take this opportunity to thank the Royal Astronomical Society of Canada and the editors of the JOURNAL for their kind co-operation in allowing us to use the JOURNAL for the publication of these notes. The magazine *Popular Astronomy* began to publish observations and miscellaneous notes on variable stars when the Association was formed in 1911, and continued the Notes until it ceased publication in December 1951. From 1936 through 1948, individual observations of the variables were printed in *Harvard Annals*, vols. 104, 107, 110, and 116. Since 1948, the observations have been printed in the *Quarterly Reports of the A.A.V.S.O.*, published by the Harvard College Observatory.

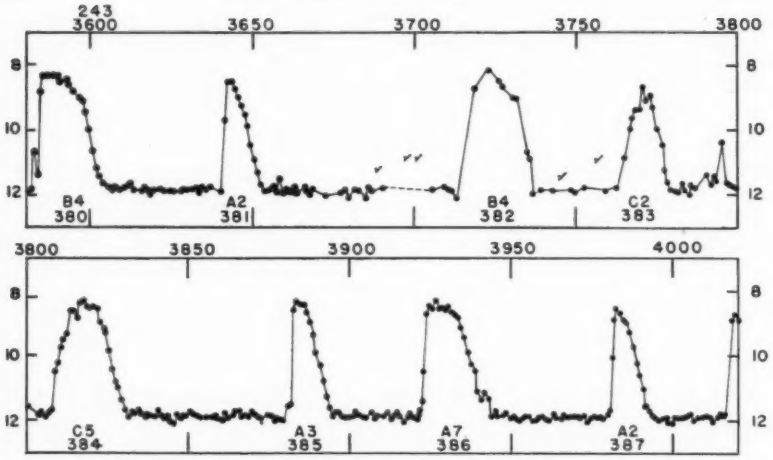
It is hoped that these Notes will be of interest to anyone with a liking for astronomy, and particularly observational work. We plan to include items of current significance to observers, as well as unusual light curves and various notes contributed by our members. For each month, we give a list of those who have sent in variable star observations, with the number of variables they observed, and the total number of estimates they made during the month. In a later issue we shall give a list of contributors to the Nova Search Programme, with a list of the fields each watches, and the number of nights the fields were checked.

The names of the observers may give some hint of the universality of interest in the visual observations of variable stars. During the fiscal year, 1950–1951, we received nearly 50,000 observations from 136 observers in 21 countries.

U Geminorum-type Variables. AE Aquarii, 203501, which has the shortest known interval between maxima, of the U Gem stars, was seen at maximum about the same time of day, on several days in succession. The elapsed time from the beginning of the brightening until it returns to normal minimum, is about one to one and one-half hours. We hope that the observations of the 1952 season will give us a lot more information about this star, for we are asking all observers to do some special work on it.

SS Aurigae, 060547, was observed at maximum on J.D. 2433896, 3943, 3990, 4034, and 4093.

SS Cygni, 213843, is the most popular and best observed of all the U Gem stars. Figure 1 is the light curve plotted from the daily mean values during 1951, which is a continuation of the curve for 1950, printed in *Popular Astronomy*, March 1951. During 1951, 1375 observations were made of SS Cygni on 294 nights, and no maxima were missed. As usual, we owe our thanks to Dr. Axel V. Nielsen for sending us 222 observations made by 8 members of the Scandinavian Astronomisk Selskab. Six maxima were observed during the year, numbers 382 to 387, as counted from the first maximum after its discovery in 1896. Table I lists the maxima, with their observed dates, and the Julian Days for magnitude 10.0 on the increasing and decreasing branches of the curves. The mean interval between maxima in 1951 is 56.5 days, as compared with the mean of 52.0 days for the 387 maxima since discovery. If anyone



SS CYGNI, 213843, DAILY MEANS IN 1951

wishes a listing of the values of the daily means which were used in plotting the curves, a copy of the table may be obtained from A.A.V.S.O. headquarters. The type of light curve is given in Table I in accordance with the classification described by Leon Campbell in *Harvard Annals*, vol. 90, no. 3, 1934.

TABLE I

No. Max.	Type	10.0 I J.D. 243+	Diff.	Max. J.D. 243+	Diff.	10.0 D J.D. 243+	Diff.	Max. Mag.
382	B4	3717	76	3723	80	3734	85	8.2
383	C2	3767	50	3770	47	3775	41	8.7
384	C5	3810	43	3818	48	3826	51	8.3
385	A3	3882	72	3884	66	3890	64	8.3
386	A7	3923	41	3927	43	3937	47	8.3
387	A2	3981	58	3982	55	3988	51	8.5

U Geminorum, 074922, had a broad maximum which lasted about 20 days from the beginning of the increase to the return to minimum, on J.D. 2433965; and a narrow maximum, which lasted less than 10 days, on J.D. 2434090. In spite of the narrowness of the latter maximum, more than 40 observations have been received of it. Many observers who have never before managed to catch U Gem at maximum were lucky enough to have clear skies during that week.

CZ Orionis, 061115, is very faint (11.8–16.2) and difficult to observe. Observations made from January to April 1952, have been conflicting, with observers reporting it brighter than 13 about every 10 to 15 days. The interval between maxima is supposed to be about 38 days.

RU Pegasi, 220912, had a well-observed 11th magnitude maximum on J.D. 2433895, and another somewhat brighter maximum on J.D. 2433978, an interval of 83 days instead of the normal of 70 days.

TABLE II

Observer	Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May	
	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.
Adams, R. M.	53	143	58	163	53	164	61	147	56	128	54	142	50	141
Ahnert, P.	42	401	29	73	2	3	28	39	5	8	25	54	35	149
Ancarani, M.	26	30	.....		28	52	4	6	12	16	19	22	21	27
Anderer, J. A.	.....		.....		.....		.....		.....		.....		1	1
Anderson, C. E.	8	50	25	104	8	13	25	55	51	60	54	85	100	164
Aoki, M.	.....		.....		23	43	.....		.....		38	68	.....	
Ball, A. R.	.....		.....		.....		.....		13	23	.....		.....	
Bappu, M. K.	11	11	28	40	42	67	32	45	24	29	36	72	31	53
Bicknell, R. H.	.....		9	44	.....		9	53	.....		.....		.....	
Blunck, V. H.	2	2	.....		.....		.....		.....		.....		4	6
Bogard, D.	49	78	5	5	.....		.....		.....		.....		.....	
Boone, A.	16	16	.....		.....		.....		.....		.....		.....	
Boutell, H. G.	5	29	7	37	7	14	5	16	5	18	5	14	5	25
Buckstaff, R. N.	17	27	15	20	.....		7	13	15	30	15	29	20	70
Cain, C. V.	3	3	.....		.....		.....		.....		.....		.....	
Chandra, R. G.	63	65	17	19	82	100	82	109	57	85	81	106	67	92
Charles, D. F.	18	23	15	15	16	22	19	25	10	10	22	28	8	8
Cobb, H.	2	2	.....		4	5	6	10	6	12	3	5	6	8
Cooke, S. R. B.	14	14	22	32	16	23	31	102	12	12	27	50	14	31
Costello, R. B.	6	6	6	6	.....		.....		.....		.....		.....	
Cragg, T.	148	161	113	123	22	24	49	55	103	106	25	25	70	75
Dafter, Mrs. R.	.....		6	16	6	24	.....		.....		.....		.....	
Darling, B.	26	105	16	38	18	29	16	31	38	102	44	131	43	91
Darnell, P.	2	24	1	1	.....		.....		.....		.....		2	8
Darsenius, G.	52	365	52	139	58	152	55	129	53	129	39	104	56	166
Diedrich, DeL.	.....		3	4	4	7	1	1	1	2	3	4	1	3
Diedrich, G.	3	5	5	9	6	12	3	5	4	5	3	5	4	7
Domke, K.	27	108	27	195	.....		29	129	.....		22	92	21	108
Drakakis, C.	13	19	.....		.....		.....		.....		.....		.....	
Elias, D. P.	81	220	.....		.....		.....		51	202	.....		42	75
Escalante, F. J.	51	62	.....		.....		.....		.....		.....		.....	
Estremadoyro, G. A.	2	2	.....		.....		.....		.....		.....		7	7
Estremadoyro, V. A.	.....		.....		4	5	4	6	6	6	13	13	18	27
Fernald, C. F.	145	265	262	468	166	292	2	2	5	5	41	67	131	320
Fernald, E. S.	8	10	9	15	.....		2	2	2	2	1	1	3	3
Ficonetti, R.	.....		14	34	.....		27	38	.....		19	28	16	27
Fisher, Y. W.	.....		.....		6	163	.....		.....		6	82	11	60
Ford, C. B.	51	57	88	94	76	78	89	91	107	116	130	131	136	143
Galbraith, W. H.	51	260	49	233	46	173	43	103	48	165	47	87	42	69
Goodsell, J. G.	2	2	.....		4	4	.....		.....		.....		.....	
Greenley, R. M.	83	129	75	108	9	9	19	19	25	25	64	70	64	76
Halbach, E. A.	.....		.....		.....		.....		7	7	.....		.....	
Hales, W. L.	.....		3	7	.....		.....		.....		.....		.....	
Harris, P.	5	10	.....		.....		.....		.....		.....		.....	
Hartmann, F.	166	183	166	183	166	180	159	167	145	154	124	134	127	138
Hiett, L.	.....		.....		.....		.....		.....		.....		9	11
Howarth, M.	.....		.....		.....		19	19	.....		.....		22	39
Isaak, G.	.....		.....		1	72	.....		.....		11	54	7	24
Jahn, A.	6	51	.....		.....		.....		.....		.....		.....	
Jerabek, H. S.	7	15	7	7	2	2	4	4	9	9	.....		9	13
Kanda, S.	4	30	.....		.....		.....		.....		.....		.....	
Karatzas, K. D.	.....		.....		1	7	.....		.....		.....		.....	
Kato, H.	.....		.....		29	45	.....		.....		.....		.....	
Kelley, L. A.	3	4	10	14	.....		31	39	24	32	24	24	14	14
Kelly, F. J.	10	13	.....		12	17	10	10	14	14	11	12	12	13
Kirchhoff, P.	.....		.....		.....		.....		.....		.....		35	54
Knowles, J.	28	56	5	39	8	36	12	23	5	7	2	3	1	1
deKock, R. P.	134	522	126	554	111	503	105	423	100	436	111	479	132	634
Lacchini, G. B.	10	10	79	83	.....		113	220	123	402	118	436	104	141
Leutenegger, E.	27	42	6	9	.....		.....		.....		.....		.....	
LeVaux, H. A.	97	99	121	122	50	50	60	60	135	137	.....		7	7
Mayall, M. W.	.....		1	4	.....		.....		.....		.....		.....	
Melville, E. C.	11	14	21	28	24	57	24	76	21	38	18	51	14	24
Miller, W. A.	30	45	8	12	13	22	22	30	23	29	17	18	26	50
Milone, L. A.	.....		.....		9	14	23	63	19	23	19	30	30	46
Montague, A. C.	.....		.....		.....		13	21	16	23	11	16	.....	
Morrisby, A. G. F.	33	112	25	25	54	113	.....		40	46	.....		23	40
Motley, G.	18	21	17	17	8	8	.....		.....		.....		.....	
Ohta, A.	.....		.....		12	47	.....		.....		.....		.....	
Oravec, E. G.	51	111	74	190	57	153	65	227	69	250	92	292	77	194
O'Sullivan, W. H.	14	41	17	40	29	78	15	32	12	37	12	29	18	23
Overbeck, M. D.	24	68	17	41	22	32	19	36	16	40	21	81	29	99
Owen, T.	.....		.....		.....		.....		3	15	.....		.....	
Parker, P. O.	28	28	.....		.....		17	19	.....		35	35	23	23
Pearcy, R. E.	23	24	17	19	5	5	6	6	9	9	6	6	24	24

TABLE II—*continued*

Observer	Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May	
	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.	No. Var.	No. Est.
Peltier, L. C.	39	140	52	202	39	89	27	59	52	140	38	73	55	202
Peter, H.	39	355	44	218	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Pierson, E. W.	75	85	60	92	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Pohl, E.	14	38	11	78	. . .	. . .	16	40	. . .	. . .	15	128	18	68
Reeves, W. P.	1	2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Renner, C. J.	180	183	192	193	89	89	54	56	175	175	113	113	205	205
Richter, G.	7	31	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Rick, L.	2	2	1	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3	4
Rosebrugh, D. W.	28	115	27	175	31	100	20	111	17	64	20	133	21	83
Santandrea, G.	. . .	. . .	. . .	. . .	. . .	. . .	2	2	. . .	. . .	. . .	. . .	. . .	. . .
Segers, C.	13	40	11	23	. . .	. . .	. . .	. . .	11	60	13	15	20	43
Semos, E.	. . .	. . .	. . .	. . .	1	2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Singer, B.	4	49	2	22	2	5	. . .	. . .	2	14	. . .	. . .	. . .	. . .
Snow, D.	9	12	. . .	. . .	2	2	7	8	. . .	. . .	4	4	9	9
Stevens, W. A.	23	26	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Taboada, D.	94	104	141	223	169	305	123	127	93	101	92	165	56	69
Tarbell, E. D.	9	14	10	23	. . .	. . .	. . .	. . .	. . .	. . .	13	20	. . .	. . .
Tarwater, C.	19	34	15	30	15	15	14	16	. . .	. . .	. . .	. . .	. . .	. . .
Tsuneoka, Y.	. . .	. . .	9	50	. . .	. . .	9	25	. . .	. . .	. . .	. . .	. . .	. . .
Upjohn, L. N.	40	50	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Venter, S. C.	28	47	21	34	28	46	23	42	22	43	17	21	27	54
Weber, J. A.	36	36	22	22	. . .	. . .	. . .	. . .	. . .	. . .	30	30	20	20
Wells, K. A.	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	5	5
Whitehill, S. L.	. . .	. . .	5	5	6	6	4	4	. . .	. . .	5	5	. . .	. . .
Yamada, T.	32	70	32	71	7	17	17	41	. . .	. . .	17	34	24	124

UV Persei, 020356, has not been observed at maximum since March 1950. It is supposed to have an interval of 300 days between maxima.

R Coronae Borealis-type Variables. None of the stars of this type on the A.A.V.S.O. programme has shown any activity for several years. SU Tauri, 054319, decreased a little during the latter part of 1951, but recovered again, and at present is nearly constant.

Two New "Leon Campbell Observatories." On September 22, 1951, Sr. Domingo Taboada of Puebla, Mexico, dedicated his "Observatorio Leon Campbell." Dr. Harlow Shapley and Mr. Watson Davis, who were in Mexico for the celebration of the 400th Anniversary of the founding of the University of Mexico, were among the distinguished guests invited to assist at the dedication. Sr. Taboada has one of the finest-equipped private observatories to be found anywhere.

Early in October 1951, Mr. Chrysostomos Drakakis, of Athens, Greece, received the optical parts for a 4½-inch refractor, sent to Greece through the co-operation of the Harvard Observatory, the A.A.V.S.O., Mr. Campbell, and the United States government. On November 8, we received some variable star observations made with the "Leon Campbell Telescope." Mr. Drakakis is to be congratulated for his promptness in making his tube and mounting, and getting the telescope in good working order.

Observations received from November 1951 to May 1952. Observations were received as follows: in November, 73 observers contributed 5,626 observations; December, 61—4891; January, 54—3595; February, 55—3237; March, 50—3601; April, 54—3956; and May, 63—4538. Table II gives a list of the observers, with the number of stars each one observed, and the number of observations made, for each month.

Harvard College Observatory
Cambridge 38, Massachusetts
June 9, 1952

METEOR NEWS

By Peter M. Millman, *Dominion Observatory, Ottawa*

Montreal Perseid Observations

One of the most active centres of the Society in carrying out worthwhile programmes of observation has been the Montreal Centre. Their observing activity is not restricted to one field but includes solar work, variable stars, auroral recording, meteor observations, nova search, and the general popularization of astronomy through open nights and special demonstrations with various telescopes.

Under the able leadership of Miss I. K. Williamson the Montreal Centre has contributed some excellent visual observations of a number of major meteor showers. Through Mr. E. E. Bridgen they also report any bright fireballs that have been noted in the Montreal district.

I am summarizing here the visual Perseid observations made in Montreal during four summers 1946, 1947, 1949, 1950. The observations were carried out by a group of observers and most of the meteors reported were plotted on star maps. A record of the group total was kept in the usual way with the time of each meteor, magnitude estimate, and generally the colour, being noted.

Observations were carried out on one night during each Perseid return. In 1946 there was a full moon right at the maximum with sky clear except for light cirrus during the second half of the observing period. In 1947 the moon was between last quarter and new but a bright aurora interfered for most of the observing period. In 1949 the moon was a few days past the full with some clouds at beginning and end of the observing period. In 1950 conditions were perfect with a clear sky and no moon.

The observers, recorders and timekeepers who took part are listed below:

1946. August 11–12—Miss L. Beaulieu, R. Brodeur, Miss T. Charland, D. Garneau, J. W. Gillon and son, J. E. Guimont, G. Hearn, F. W. Henshaw, W. H. C. Morton, Miss I. K. Williamson, Mrs. D. Zorgo.

1947. August 11–12—Miss L. Beaulieu, G. Bloom, R. Brodeur, D. Garneau, C. M. Good, D. Newman, H. Newman, P. Scott, Miss I. K. Williamson, Mrs. J. Wright, K. Zorgo.

1949. August 12–13—W. H. Birtles, W. J. Cullinan, F. DeKinder, J. P. Duhaime, Mrs. J. P. Duhaime, C. M. Good, D. Lingeman, D. A. McAlpine, F. P. Morgan, T. Noseworthy, P. S. Scott, R. Venor, Miss I. K. Williamson, Mrs. J. Wright.

1950. August 11–12—W. H. Birtles, W. J. Cullinan, J. P. Duhaime, Mrs. J. P. Duhaime, C. M. Good, D. Newman, H. Newman, T. Noseworthy, P. S. Scott, R. Venor, Mrs. J. Wright, Miss I. K. Williamson.

A summary of the total numbers of meteors observed is given in Table I and the magnitude distributions have been listed in Table II. There is the expected fainter mean magnitude for 1950, which results from the clear sky and the complete absence of a moon. The faint mean magni-

TABLE I

Date	Period of Observation E.S.T.	Mean No. of Observers*	Meteors Observed	
			Perseids	Non-Perseids
1946 Aug. 11 – 12	20.30–23.30	5	62	10
1947 Aug. 11 – 12	21.10–03.10	6	67	8
1949 Aug. 12 – 13	21.10–02.10	7	165	40
1950 Aug. 11 – 12	22.50–02.30	7	387	50
		Totals	681	108

* Exclusive of recorder and timekeeper

TABLE II

Magnitude	−1	0	1	2	3	4	5	6	Totals	Mean Mag.
1946 Aug. 11 – 12										
P		1	9	8	26	12	6		62	2.82
N			1	1	4	3	1		10	3.20
1947 Aug. 11 – 12										
P	2	2	14	24	20	5			67	2.09
N			1	3	3	1			8	2.50
1949 Aug. 12 – 13										
P	2	1	47	52	44	18	1		165	2.17
N			12	10	8	8	2		40	2.45
1950 Aug. 11 – 12										
P	6	8	69	87	106	80	29	2	387	2.67
N			6	9	17	9	9		50	3.12

tudes for 1946 are a little surprising as it was near the full moon on this occasion. It is possible that some personal equation enters here as 1946 was the first year this group of observers was active following the war.

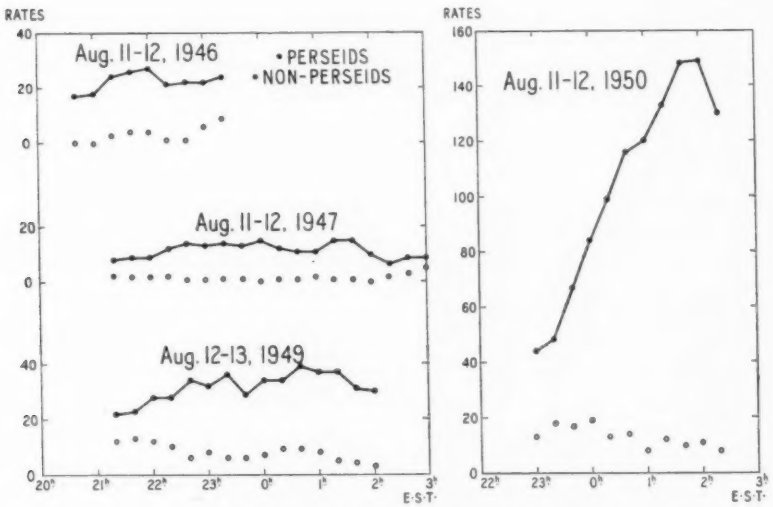
The estimation of the colour of a meteor is difficult, particularly for the fainter objects. The results of the Montreal colour estimates are summarized in Table III. The greater percentage of blue meteors for the fainter magnitudes is probably a subjective effect.

TABLE III

OBSERVED PERCENTAGES OF METEOR COLOURS

	Blue	White	Green	Yellow	Orange	Red	Total No. of Meteors
Magnitudes −1 to 2	34	37	5	8	9	7	312
Magnitudes 3 to 6	48	32	1	4	10	5	350

The hourly rates of the meteors observed have been reduced to a standard of six observers using the factors published in the JOURNAL, vol. 28, p. 139, 1934, and have been plotted in the figure. No weather factor has been applied. The high rate for 1950, when weather conditions were perfect, is very marked. However, from other evidence, including our Ottawa observations, I think 1950 was a particularly good Perseid return quite apart from favourable weather conditions.



The hourly rates of meteors observed visually at Montreal and reduced to a standard observing unit of six observers, plotted against Eastern Standard Time.

In addition to the main group Mrs. E. Dawes and friends observed 123 meteors at Lachute from Aug. 10 to Aug. 14, 1950, and Earl Milton made independent observations of 43 meteors at St. Laurent during the same period. Mr. R. Venor made some photographic exposures in connection with the 1950 observations and secured a very fine photograph of one particularly bright Perseid. These and other photographic observations will be described in more detail elsewhere.

The Montreal Centre also carried out a really exceptional programme of observation of the 1946 Giacobinid meteor shower and this work will be reported along with other Canadian observations of the same shower. In the future we will be looking for continued observational activity of the high standard already produced by the Montreal group.

It is a pleasure to acknowledge the assistance of Miss M. Rettie in preparing this material for publication.

OUT OF OLD BOOKS

By Helen Sawyer Hogg

The Introduction of the Coppernican System to England

II. John Dee and the Circle at Mortlake

John Dee (1527–1608), ardent mathematician and astrologer, was Robert Recorde's successor in the dispersal of knowledge of the Copernican system through England. During the third quarter of the sixteenth century, John Dee was the guiding spirit of the English school of mathematics. In fact, after Robert Recorde's death in 1558, there was no one to equal him. As a writer in English he was inferior both to Recorde and to his own pupil Thomas Digges, who was to follow him. In learning and scholarship, however, Dee was probably superior to the very remarkable Recorde. Most of Dee's important printed works were in Latin, and he was therefore better known on the Continent than was Recorde.

In the same year, 1556, in which Robert Recorde published the first discussion of the Copernican system in English, John Dee wrote a Latin preface to a revision in Latin of Reinhold's Prutenic Tables, done by John Feild. Dee stated that he had persuaded his friend Feild to compile these tables on the basis of the Copernican theory because the old tables would not be satisfactory under the new system. He also expressed the hope in this preface that the "Herculean labours" of Copernicus, Rheticus and Reinhold had become known to the English people. Because Dee spoke with the voice of authority, his opinion was a great boost for the Copernican system among the educated people of England.

On the authority of Francis Johnson, from whose valuable book *Astronomical Thought in Renaissance England* we have been given permission to quote by The Johns Hopkins Press, for the two decades after Recorde's death in 1558, Dee was the supreme scientific authority in England. He was chief advisor to the principal English voyages of the period, beginning in 1553 with the first Muscovy venture, on which Recorde also gave advice. A good account of his career has been published by Charlotte Fell Smith, *John Dee*, London, 1909, from which we also quote.

John Dee was born in London, the son of Rowland Dee. The exact date of his birth is known because of his interest in astrology, from a horoscope of his own drawing, as July 13, 1527. He had a Welsh descent of great genealogical antiquity. His father held a court appointment as gentleman server to Henry VIII. He was taught Latin at an early age, and attended

the Grammar School at Chelmsford, which has always claimed him as one of its most famous alumni. In November 1542, at the age of fifteen, he left Chelmsford and entered St. John's College, Cambridge. In his autobiography, *Compendious Rehearsall*, he gives a vivid account of his diligence as a student. It would appear that he had both an iron constitution and an iron will.

> In the years 1543, 1544, 1545, I was so vehemently bent to studie, that for those years I did inviolably keep this order: only to sleep four houres every night; to allow to meate and drink (and some refreshing after) two houres every day; and of the other eighteen houres all (except the tyme of going to and being at divine service) was spent in my studies and learning.

In 1546 he received his B.A. degree from St. John's College. Later this same year Trinity College was founded by Henry VIII, and Dee was appointed one of the original fellows, and under reader in Greek. Here he

JOHN DEE, 1527–1608

created quite a sensation by the mechanical arrangements he made in staging a Greek play when a scarabaeus carrying an actor was made to mount to the ceiling. Indeed, his reputation as a sorcerer apparently dates from this incident. He also engaged in sterner studies, however, turning to astronomy where he made "thousands of observations (very many to the hour and minute) of the heavenly influences and operation actuall in this

elementall portion of the world." These were later published in various Ephemerides.

His first journey abroad was made in May 1547 to confer with the learned men of the Dutch Universities in mathematics. He spent several months in the Low Countries, forming close friendships with noted men such as Gerard Mercator. Indeed, he brought back to Cambridge two large globes made by Mercator, and an armillary ring and staff of brass. These he later gave to the Fellows and students of Trinity College, but they are not now to be found.

In 1548 he entered the University of Louvain as a student, and acquired a great reputation for learning there. Many distinguished people came to Louvain from various countries in Europe, to see Dee and learn from him. Among the more interesting names we read one of special astronomical interest, Sir William Pickering of England, afterwards ambassador to France, who came to study astronomy "by the light of Mercator's globes, the astrolabe, and the astronomer's rings of brass that Frisius had invented." It is presumed that Dee graduated from Louvain as Doctor, since that title was used for him afterwards.

In 1550 he moved on to Paris where he gave a course of free public lectures and readings on Euclid. Apparently his lectures were an astonishing success. His audience was so large that the mathematical schools would not hold them, and many eager students were forced to climb up outside the windows. From this vantage point, if they could not hear the speaker they could at least see him! Few modern lecturers have the satisfaction of seeing their audience rise to such a height of enthusiasm. From these years spent in Louvain and Paris, Dee for the rest of his life maintained a lively friendship and correspondence with professors and doctors in almost every important university on the Continent.

Although he was invited to become a King's Reader in mathematics at Paris University, he had made up his mind to return to England, and did so in 1551. Upon his return he obtained an introduction to Secretary Cecil and to King Edward VI. He had already written and dedicated to the young King two manuscripts: *De usi Globi Coelestis,* 1550, and *De nubium, solis, lunae, ac reliquorum planetarum,* 1551. A happy result of the dedication was the gift to Dee of an annual royal pension of a hundred crowns, afterwards exchanged to his disadvantage for a rectory in Worcestershire. From this time on Dee proved to be a close friend and advisor of the royal family. When Mary Tudor succeeded her brother as queen in 1553, Dee was asked to calculate her nativity. He began a correspondence with Princess Elizabeth and cast her horoscope. Apparently by now Dee's powers of "magic" had become so well known that he was accused by one George Ferrys of striking one of his children blind and killing another by magic, and working a spell against the Queen. Dee was

put into prison on these charges, but finally was cleared in 1555. His astrological influence was very great, and when Elizabeth succeeded her sister on the throne, Dee was commissioned to name an auspicious day for the coronation. Though nowadays we have no faith in astrology, we have to admit that his selection of January 14, 1559 was certainly the start of an era of glory for England and Queen Elizabeth.

His friendship with Queen Elizabeth continued throughout her lifetime, and she relied upon him in moments of stress. When a wax image of the Queen was found lying in Lincoln's Inn Fields with a huge pin stuck through the breast (an omen of impending death), messengers were hurriedly dispatched to Dee who hastened to solace her Majesty, and assure her she would come to no harm. When the famous comet of 1576 appeared, throwing the Queen and the Court into a perturbed state, Dee was summoned to give his interpretation of the phenomenon. His home at Mortlake on the Thames was near the favourite residences of Elizabeth, and the journey to and from London was made by water. When Dee became dangerously ill at Mortlake in 1571, Elizabeth sent two of her own physicians to attend him. She would sometimes call on him when she went out riding in Richmond Park. One windy day in March 1576 she seems to have chosen an inauspicious moment for her visit, as Dee's first wife (whose identity is unknown) had been buried just four hours previously. This unfortunate circumstance, however, did not prevent the Queen from seeing and admiring Dee's wonderful convex mirror, after which she rode away "amused and merry, leaving the philosopher's distress at his recent bereavement assuaged for the moment by such gracious marks of royal interest and favour." Incidentally one of Dee's mirrors, possibly this one, a solid pink-tinted glass the size of an orange, is now in the British Museum.

The letter that Dee wrote the Queen from the Continent in 1588, to congratulate her upon the defeat of the Spanish Armada has become a classic example of the prose and erudition of the day, and is reprinted by Ellis in his *Letters of Eminent Men,* and in facsimile by Charlotte Smith. It reads as follows:

> Most Gratious Soueraine Lady, The God of heauen and earth, (Who hath mightilie, and evidently, given vnto your most excellent Royall Maiestie, this Wunderfull Triumphant Victorie, against your mortall enemies) be allwaies, thanked, praysed, and glorified; And the same God Almightie, euermore direct and defend your most Royall Highnes from all evill and encumbrance: and finish and confirme in your most excellent Maiestie Royall, the blessings, long since, both decreed and offred: yea, euen into your most gratious Royall bosom, and Lap. Happy are they, that can perceyue, and so obey the pleasant call, of the mightie Ladie, OPPORTVNITIE. And, Therfore, finding our duetie concurrent With a most secret beck, of the said Gratious Princess. Ladie OPPORTVNITIE, NOW to embrace, and enioye, your most excellent Royall Maiesties high favor, and gratious great Clemencie, of CALLING me, Mr. Kelley, and

our families, hoame, into your Brytish Earthly Paradise, and Monarchie incomparable: (and, that, abowt an yere since: by Master Customer Yong, his Letters,) I, and myne, (by God his fauor and help, and after the most convenient manner, We can,) Will, from hencefurth, endeuour our selues, faithfully, loyally, carefully, warily, and diligently, to ryd and vntangle our selues from hence: And so, very devowtely, and Sowndlie, at your Sacred Maiesties feet, to offer our selues, and all, Wherein, we are, or may be hable, to serve God, and your most Excellent Royall Maiestie. The Lord of Hoasts, be our help, and gwyde, therein: and graunt vnto your most excellent Royall Maiestie, the Incomparablest Triumphant Raigne, and Monarchie, that euer was, since mans creation. Amen.

Trebon. in the kingdome of Boemia
the 10th. of Nouebre: A. dm: 1588: style Weser
Your Sacred and most excellent
Royall Maiesties
most humble and dutifull
subiect, and Servant
John Dee

In 1581 Dee had become acquainted with a charlatan Edward Kelley. From then on Dee's philosophical researches were concerned entirely with necromancy. Dee and Kelley followed the lure of the philosopher's stone around Europe, for some years in company with Albert Laski. Shortly after writing his famous letter to the Queen, Dee returned to England in 1589, and in 1595 was made Warden of Manchester College. In this position he had to make official visits of inspection to the Grammar School. Dee's remarks upon his visit of August 5, 1600 are interesting in that they show that official displeasure at students' knowledge is not confined to the twentieth century.

I visited the Grammar Schole, and fownd great imperfections in all and every of the scholers, to my great grief.

His last years were spent in great poverty, and failing health of body and spirit. When he needed funds, he sold pieces of his silver plate which he had acquired in more auspicious times. His last entry in his diary was of April 6, 1601, but he did not pass away until December 1608. He must have been a striking figure. His cousin Aubrey describes him as "of a very fair clear sanguine complexion, with a long beard as white as milk—a very handsome man—tall and slender. He wore a goune like an artist's goune with hanging sleeves."

It is unfortunate that in the later years Dee's interest in astrology and spiritualism overshadowed, both for his contemporaries and his biographers, his knowledge and love of sound science. The populace regarded Dee, by 1564, not as a highly equipped mathematician, geographer and astronomer, but rather as a conjuror and magician of doubtful reputation. One of Dee's finest works is the English preface to Henry Billingsley's first English translation of Euclid's *Elements* in 1570. Even in this preface

Dee feels called upon to defend himself from charges of having dealings with the devil. All critics agree that this preface was an outstanding piece of work, actually a treatise on the proficiency and advancement of scientific learning written 35 years before Francis Bacon's English work. According to Charlotte Smith:

> A study of this preface alone must convince any reader that the author was no charlatan or pretender, but a true devotee of learning, gifted with a far insight into human progress. He covers in review every art and science then known, and some "until these daies greatly missed" (his comments on music and harmony are truly remarkable), and comes back to his own predilection—arithmetic, "which next to theologie is most divine, most pure, most ample and generall, most profound, most subtele, most commodious and most necessary". He quotes Plato to show how "it lifts the heart above the heavens by invisible lines, and by its immortal beams melteth the reflection of light incomprehensible, and so procureth joy and perfection unspeakable." Speaking of the refraction of light, he foreshadows the telescope as he describes how the captain of either foot or horsemen should employ "an astronomical staffe commodiously framed for carriage and use, and may wonderfully help himself by perspective glasses; in which I trust our posterity will prove more skilfull and expert and to greater purpose than in these days can almost be credited to be possible." Then he alludes to a wonderful glass belonging to Sir William P., famous for his skill in mathematics, who will let the glass be seen. The passage seems to show that looking-glasses were not common, or that this particular one was a convex mirror.

Dee's greatest influence, however, was probably not from his writings but from the circle of people that he gathered about him at his home in Mortlake, and the correspondence which he sent out all over the Continent. When he was over forty, Dee established himself at his mother's house at Mortlake on the Thames. It was an old rambling place, situated between the church and the river. Dee added to it bit by bit, so that eventually it had laboratories for experiments, libraries and rooms for workers. Johnson considers that John Dee and the people associated with him at Mortlake constituted the scientific academy of England.

One of the works undertaken by Dee and his pupil Thomas Digges was observation of the historical new star of 1572, which Tycho Brahe (with whom Dee was acquainted) also observed. This new star, representing as it did, change in what Aristotle considered a changeless region of the heavens, struck a great blow to Aristotelian theory. Dee and Digges ranked next to Tycho in their parallax measures establishing that this star was in the "celestial, not in the elementary region" of the sphere.

Of the importance of Mortlake, Johnson says (page 137):

> The center of Dee's activities was his home at Mortlake, near London, where his library, his laboratory, and his astronomical instruments were located. London, and not the universities, became the scene of scientific study and scholarship in this period.
>
> During the third quarter of the century, John Dee and his friends and pupils constituted the scientific academy of England. Through Dee's intimate acquaintance and

correspondence with all the most eminent scientists on the Continent, the English group was kept in constant touch with all the latest ideas and discoveries originating abroad. Dee's unheeded plea to Queen Mary that the ancient books and manuscripts dispersed with the destruction of the monasteries be recovered, in order to found therewith a great National Library, is well known. When he perceived that nothing was going to come of this suggestion, he set about forming his own library of scientific books and manuscripts, which, by 1583, had grown to over four thousand volumes. It was undoubtedly the greatest scientific library in England, and probably not surpassed in Europe, for Dee not only had collected a vast store of important medieval manuscripts on science (which he could get the more readily because they were little valued by the plunderers of the monastic houses), but he had also seen to it that all the latest printed works on the mathematical sciences should be found on his shelves.

This great library was always at the disposal of Dee's fellow scientists among his friends and pupils. If one believes that the first essential and the true center of any university is its library, Dee's circle might truly be termed the scientific university of England during the period from about 1560 to 1583. Mention may be made, in passing, of the presence of two copies of Copernicus' *De revolutionibus* on Dee's shelves, along with the works of Nicholas of Cusa and the first Greek edition of Ptolemy's *Almagest*.

Dee also realised the importance of the technical arts in scientific work and their value in developing and perfecting new and better instruments for scientific experiment and observation. Working with Richard Chancellor, who was an expert mechanician as well as a scholar, he constructed a number of astronomical instruments with specially devised transverse divisions on the scale, so as to make possible finer and more accurate readings. His most prized instrument was a huge radius astronomicus or cross-staff, ten feet long, "having the staff and cross very curiously divided into parts equall, after Richard Chancellour's Quadrante-manner. The great instrument was in such a frame placed and layd, that it might most easily be weilded of any man to any position for practise in heavenly observation or mensurations on earth."

The position of Recorde and Dee as the outstanding and most influential English scientists at the beginning of the second half of the sixteenth century was universally conceded by their contemporaries among their countrymen. Consequently, their support of the Copernican theory has a special significance in the history of English astronomy.

NOTES AND QUERIES

The Date of Stonehenge

It has long been believed that the great stone monument on Salisbury Plain was constructed and oriented on astronomical principles. The famous English astronomer Sir Norman Lockyer considered that the temple was intended to mark the position of the sun at sunrise about the summer solstice. The scale of the monument is not always appreciated. Besides the existing remains of the inner temple consisting of massive sarsens and trilithons there are indications of an outer concentric circular wall of earth 300 feet in diameter which opens on to an avenue running between two parallel banks of earth for a distance of a mile or more. These and other features of the monument are now almost obliterated. Lockyer believed that the avenue was originally aligned with the rising sun at summer solstice. The avenue is not now so aligned, since the slow decrease in the obliquity of the ecliptic now causes the sun to appear to rise somewhat nearer to the east than it is presumed to have done when the monument was built. From the rate of change of the obliquity of the ecliptic Lockyer estimated the date of the construction of Stonehenge as between 1900–1500 B.C. Fresh interest attaches to Lockyer's interpretation since the date of the temple has now been estimated from a modern technique based on examining charcoal fragments believed to be contemporary with the construction of the temple. By measuring the intensity of radiation from radioactive carbon of atomic weight 14 the age of the temple has been estimated by Professor Willard Libby of the University of Chicago as about 3800 years in striking agreement with Lockyer's estimate.

R. L. B.

Telescopes in South Africa

Astronomy has come a long way in South Africa since the Royal Observatory of the Cape of Good Hope was established shortly after 1814 as an aid to navigators, and Sir John Herschel started his cataloguing of the southern nebulae in 1834. In more recent times a number of southern-hemisphere observatories have been established.

There are three powerful reflectors in South Africa. The largest is the 74-inch telescope of the Radcliffe Observatory at Pretoria. This was put into operation about three years ago and has been used for photographing the southern nebulae. The 60-inch Rockefeller telescope of the Boyden

Station of the Harvard Observatory near Bloemfontein is being turned into a Schmidt-type telescope. A photoelectric photometer and a spectrograph have been in use on the 60-inch. The third reflector is the so-called ADH telescope, a 36-inch Schmidt, covering about 20 square degrees of sky. This telescope is also at the Boyden Station, but is operated jointly by Armagh, Dunsink and Harvard Observatories. It is a powerful instrument for studying the southern Milky Way.

Among the refractors greater than 20 inches in diameter, the largest is the 27-inch visual refractor of the Lamont-Hussey Observatory at Bloemfontein, used for the observation of double stars. The 26½-inch Union Observatory telescope at Johannesburg is maintained by the government of the Union of South Africa, and is used for the study of asteroids, comets and double stars. This observatory collaborates with Leiden Observatory in Holland. The Yale-Columbia station at Johannesburg has a 26-inch photographic refractor, used for parallax determinations and colours of selected southern stars. It is planned to move this station to Australia because of the lights in the growth of the city. The Royal Observatory of the Cape of Good Hope, the oldest of the observatories in South Africa, has a 24-inch photographic refractor. It is used for parallax and magnitude determinations.

C. A. C.

Crater Elegante

A little-known crater in Mexico, in the region of Pico del Pinacate, in the wild, northern region of Sonora, was visited by Allan O. Kelley, and reported by him in the May 1952 issue of *The Scientific Monthly*. Kelley became interested in the crater as a result of an article by Wilson McKenney about the Papagoo Indians and their sacred cave on Pico del Pinacate; in this article the crater is mentioned.

Crater Elegante is in a region of volcanic cones; the arc of the rim of the crater cuts an old cinder cone exactly in half. It is between Ungava crater and the Arizona meteor crater in size, having a diameter of about a mile and a depth of about 600 feet; the ratio of width to depth fits the relation which has been found to hold for impact craters. The floor of the crater is between 300 and 400 feet below the level of the surrounding surface.

The impact apparently cut through five layers of hard lava flows, which stand as cliffs about 200 feet high along the edge of the crater. The surface of the old lava rock had been remelted to a depth of at least half an inch and in places shows a flow pattern.

Kelley found no meteoric material on his brief visit. This does not rule out the possibility that the crater was formed by the impact of a meteorite, however.

R. J. N.

Planetensektion der Sternfreunde, Germany

This organization was founded in 1947 as a special section of the German amateur association, "Bund der Sternfreunde" (founded in 1921). The section now has eleven local astronomical unions and people's observatories and about one hundred individual members co-operating in the special research of lunar and planetary observation.

The organization is directed by a chairman, at present Mr. E. Maedlow, Berlin. Also, there are appointed nine members to act as recorders for the following sections: moon, Mercury, Venus, Mars, Jupiter, Saturn, planetary photometry and photography, planetoids and eclipses. The Section is publishing a bi-monthly bulletin, *Mittcilungen fuer Planetenbeobachter,* giving instructions to observers and reports of observations. Summaries of the scientific work will be printed in the astronomical journals *Die Sterne* and the *Astronomischen Nachrichten.*

The Chairman and Council are anxious to deepen international co-operation. In this connection it is pleasant to report the good collaboration with the sections of the British Astronomical Association and the Association of Lunar and Planetary Observers in the United States. During August 12–15, 1951, the Section organized an international conference of lunar and planetary observers at Munich University Observatory. More than 65 participators from U.S.A., Switzerland, Austria and Germany were present; there were also representatives of government, press, radio and professional astronomy. In connection with the conference there was an exhibition showing material about world-wide amateur scientific work.

Readers interested in correspondence, both about scientific work and about international co-operation, may write to the Foreign Secretary of the Section at Privatsternwarte, München 9, Lengmoosstrasse 6, Germany.

Gunther D. Roth, *Foreign Secretary.*

Centenary of Laval University

During the period Sept. 19–22 Laval University in Quebec will celebrate its centennial jubilee; and, taking note of this, a large number of learned societies of Canada held their annual meetings at Quebec during the year.

Among these, the Canadian Association of Physicists held its annual Congress on the last three days of May, and the Royal Society of Canada utilized the first four days of June for its Annual Meeting. Attending the former from the David Dunlap Observatory were Dr. C. A. Chant, who is one of the earliest members of this society, and Dr. R. E. Williamson, who took part in a Symposium on Radiation Physics; attending the latter society were Dr. C. A. Chant and Dr. Helen Hogg.

One of the pleasant incidents of the occasion occurred on Tuesday, June 2. As stated in the last issue of this JOURNAL (p. 110), an edition of Dr. Chant's book "Our Wonderful Universe" has just been published in the French language. The translation is by Paul-H. Nadeau and the book is produced in the city of Quebec, under the auspices of the Quebec

P.-H. Nadeau, C. A. Chant, Monsignor Vandry, A. Duberger.

Centre of the Royal Astronomical Society of Canada. A small deputation from the Centre waited upon Monsignor Ferdinand Vandry, Rector of the University, and presented him with an appropriately bound copy of the book. The scene is recalled by the accompanying photograph which appeared in *Le Soleil*.

R. J. N.

J. W. STEIN, S.J.

On December 27th of last year the well-known Jesuit astronomer, Father J. W. Stein, died at the age of 80. Dutch by birth and trained in astronomy at Leiden, he had been Director of the Vatican Observatory since 1930. Father Stein, respected as an able astronomer and as a devout priest, will be missed by his many friends and correspondents among astronomers the world over.

J. F. H.

REVIEW OF PUBLICATIONS

Physique de la Planète Mars, by Gerard de Vaucouleurs. Pages 420, plates 12; 5½ × 7½ inches; paper bound. Paris, Albin Michel, 1951. Price 825 Fr.

Many readers will no doubt be familiar with an excellent little book of a popular nature entitled *The Planet Mars* by Gerard de Vaucouleurs which appeared in an English translation in 1950 and which was reviewed in this JOURNAL (vol. 44, p. 202, 1950). The same author has now produced this much more extensive and technical work on the "Physics of the Planet Mars."

The tantalizing uncertainties that exist still concerning many of the surface features of Mars appeal to the imagination of everyone who has any knowledge of astronomy. These the reader will find presented in a sober, objective manner, the problem stated clearly, the results of various investigators presented fairly, and finally the author's own comments, well balanced and cautious. For example, the author discusses in detail the problem of the changes in form and colour of the markings of Mars, explaining, with the help of illustrations, the observations of Antoniadi, Fournier, Lowell, Kuiper and others. He shows that, almost without doubt, the diffusion of humidity in the atmosphere is the agency whereby the changes are propagated, but the question of the exact nature of the changes he finds he must leave open. Vegetation has always seemed the most natural explanation, but some of the observational facts are difficult to reconcile with this hypothesis. On the other hand, the author is not too much impressed with the explanation by Arrhenius that the changes take place in hygroscopic material. He concludes this section with the view that "the theory of vegetation is not necessarily the only one to which we may have recourse, and in any event it would be premature to consider it perfectly established, for the analogy with our own vegetation has often been rather forced."

In other sections the book deals with the pole caps, the canals, the clouds, the atmosphere (its constitution, temperature and pressure), the winds, the dust layers (to explain the so-called violet layer), the constitution of the interior (favouring Jeffreys' iron core theory ahead of Ramsey's uniform constitution theory), and many other topics. All these topics are admirably arranged with good illustrations and tables of data and plenty of references. There is a bibliography of 78 items and an index of names

and another of subjects. The book cannot help but prove to be a most valuable reference work for anyone interested in Mars.

J. F. H.

L'étude optique de l'atmosphère terrestre, by various authors. Pages 319; 6¼ × 9½ inches; paper bound. Louvain, Imprimerie Ceuterick, 1952.

The Astrophysical Institute of the University of Liège held a colloquium in September 1951 on the subject of the optical study of the earth's atmosphere. Thirty-one papers on topics having to do mostly with photometric and spectroscopic studies of nightglow and aurorae by investigators from various countries were presented at this colloquium. These papers, some in English, the others in French, have now been published in this single volume. The papers are reports of recent researches. They are technical in nature and will be of most interest to those who are engaged in some phase of atmospheric research.

J. F. H.

The Astronomical Universe, by Wasley S. Krogdahl. Pages 599; 6¼ × 9½ inches. New York: The Macmillan Co., 1952. Price $6.25 (in Canada).

With the number of excellent astronomy text-books which have been written, it is both surprising and refreshing to find one which has an original approach to the subject, without at the same time sacrificing the basic principles. This new volume by Dr. Krogdahl, assistant professor of astronomy at Northwestern University, is designed as an introductory text-book in college astronomy. It should be of real help to teachers, particularly when they wish to expand the stellar part of the course, for more than half the book is devoted to the sun and the stellar universe. The author has obviously worked out a fresh and consistent outline (given in the front of the book) and the originality is further evident in the numerous drawings and photographs which have not previously appeared in astronomical text-books.

The five main parts of the book deal with the solar system, the anatomy of a star (chiefly the sun), the stellar population, the organization of the universe and the evolution of the universe. There are appendices on constellations, the magnitude system, and telescopes and observatories. An excellent feature is a bibliography of readily obtainable astronomical references, of interest to the average reader; one sentence comments for each reference make this list both unusual and valuable. The star maps at the end on blue back-ground are very different from those most of us have used, and require some orientation.

An excellent, rather novel feature of the book is that it gets away from starting the study of astronomy with that teacher's bugbear, the celestial

sphere. Rather it selects the laws of planetary motions and the general arrangement of the solar system as the starting point. As in any new arrangement, there are spots in the outline to which some astronomers would take exception. For example, the satellites are grouped together in Chapter VI, The Lesser Bodies of the Solar System, and it seems rather queer in the previous chapter to read about Jupiter, without its moons, and Saturn with its rings, but no moons. This reviewer would prefer to see planetary families left whole, and not split up into their constituent parts. If this arrangement had been followed to its logical conclusion the rings of Saturn would have been torn from the planet and included in the lesser bodies—a hurdle no one could take.

Many of the 275 diagrams and pictures are excellent in both their originality and their reader appeal, as for example, the time zone map for the northern hemisphere, the picture of telephone poles converging across the Utah salt flats, and the photograph of Orion which includes the stars both as point sources and as trails. Numerous photographs taken with the 200-inch Hale telescope give the reader the finest recent examples of astronomical photography. A few misprints in popular names that would confuse the student, such as Euxodus, page 152, Ophiucus, pages 455, 456, will doubtless be corrected before another printing. We all know what the author means by "The Milky Way Galaxy", but as far as this reviewer is concerned, it is an awkward expression that astronomy can do without. Why not use instead "The Sun's Galaxy"?

The fact that the author has put much thought and work into the volume is obvious in many ways, one of which is the delightful quotation at the start of each chapter.

H. S. H.

Regelmaat en Wisseling bij Zonsverduisteringen, by Prof. G. van den Bergh, vol. I (text), pages 263; 10½ × 7½ inches; vol. II (charts), charts 13, Cloth, folio. Haarlem, H. D. Tjeenk Willink & Zoon's N.V., 1951. Price 50 florins ($13.00).

This book is a study of eclipse cycles. In order to be useful, an eclipse cycle must contain an integral number of half synodic months and of half eclipse years, for that is the necessary interval of time between any two eclipses. The ancient Babylonians discovered empirically that eclipses repeated themselves at interval of 6,585⅓ days, or 223 synodic months, or 19 eclipse years, and called this period the saros. The author introduces a new period, the inex, which is 10,572 days, or 358 synodic months, or 30½ eclipse years.

The time between any two solar or lunar eclipses is shown to be a combination of multiples of these two periods. By making a saros-inex plot of the eclipses given in Oppolzer's *Canon der Finsternisse*, the author

shows graphically the characteristics of eclipse cycles, and lays the foundation for determining approximate eclipse characteristics for thousands of years into the past or future. At the end of the first volume he gives a table of the 8,000 solar and 5,200 lunar eclipses found in Oppolzer. This table is very valuable, and is the sort of thing many authors would neglect to include. The second volume is a collection of charts illustrating graphically the author's conclusions. These charts are sufficiently large to permit the print to be of readable size.

This painstaking analysis is a distinct contribution to eclipse theory. Whereas the saros will probably always be the most important eclipse cycle, there is still a useful function to be performed by the inex. This book may be recommended to those interested in eclipse theory. It is beautifully bound (unfortunately a rarity among many Continental books) and the print is large and clear. The book is written in Dutch, with a very brief summary in English.

R. F. RODGERS

MEETINGS OF THE SOCIETY

AT LONDON

The London Centre of the Royal Astronomical Society of Canada sponsored a display of astronomical instruments in the Williams' Memorial Library, London. The exhibit lasted one week, from April 18 to 25, 1952, and was manned constantly by members of the Centre. It resulted in renewed interest in astronomy—not only on the part of the public but also by the participating members.

From left to right the names of the members in the photograph are: Gordon Graham, John Middlebrook, R. H. Cole, Miss S. Bosshko, H. R. Kingston, W. G. Colgrove, A. Schoenfeldt, Henry Schoenfeldt, George Walden (President), E. Fanning (next appears the sign), Mrs. Alice Davies, Mrs. Bernard Johnson, Mrs. W. G. Colgrove, Mrs. Henry Schoenfeldt (behind model), Mrs. J. C. Higgins, E. E. O'Connor, R. E. Winters, G. R. Magee, J. C. Higgins, W. H. Adamson. The boy on the right front is Keith Faulkner.

The instruments and models shown are, left to right: Model of galaxy, sotellunium (sun, earth, moon system), plaster cast of Dresden meteorite, model of reflecting telescope, two models of the solar system, fortieth scale model of the Hale 200-inch telescope, Foucault pendulum swinging over a globe (in front of the sign), model of sun, earth, moon system, model of stellar radiant, model of planetary paths from Mercury to Jupiter, motor-driven model of solar system, out to Jupiter, planeto-zodiac.

On the table are arranged books, maps and a very interesting display of materials needed in mirror-making arranged by Gordon Graham. The mirror-making display aroused so much interest that Graham has a class of 60 interested people, about half of whom are adults.

G. R. MAGEE, *Secretary-Treasurer.*

Exhibit of London Centre, April 1952. For names see p. 172.

AT TORONTO

February 12, 1952—The meeting was held in the McLennan Physics Laboratory. The President, Mr. F. L. Troyer, was in the chair.

One candidate was elected to membership in the Society: Mrs. W. M. Tovell, 507 Riverside Drive, Toronto 9.

The speaker, Dr. Helen W. Dodson of McMath-Hulbert Observatory, University of Michigan, was introduced by Dr. J. F. Heard. Her subject was "Solar Activity Seen and Heard." The first essential in studying the sun is to reduce the glare. This may be done by reproducing it on a screen, and often a disk is inserted in the optical instrument so the main part of the sun is obscured, making an artificial eclipse. The second essential is international co-operation among astronomers so that the sun may be observed continually.

When pictures of the sun's surface are taken with integrated light, the sun-spots show up with clarity. When taken in red light, the light of the Hα line, the spots are not so clear, and appear bright rather than dark. More surprising is the additional amount of detail, such as long dark streamers which are the projection of solar prominences on the surface. The various types of these prominences were illustrated—the eruptive, tornado, dynamic, and quiescent. One of the highlights of the evening was the showing of a movie made at McMath-Hulbert of the sun-spots in action. Not even the fireworks at the Canadian National Exhibition could compare with these solar pyrotechnics, although more than one person noted the resemblance in the falling streamers and the sudden inexplicable surges of light.

Next, Dr. Dodson discussed the solar flares. These bright patches on the surface of the sun last only a matter of minutes, usually of the order of twenty minutes; even so they have a marked effect here on earth. With these solar flares are associated magnetic storms which cause so much difficulty in terrestrial communications. Dr. Dodson explained the association of these flares and the records of radio telescopes. There seemed a definite correlation between optical and radio activity although in some cases large optical flares seemed to be associated with rather small radio disturbances. Dr. Dodson admitted that she would not like to have to give an explanation of all these varied forms of solar activity.

February 26, 1952—The meeting was held in the McLennan Physics Laboratory. Mr. F. L. Troyer, President, was chairman.

The following people were elected to membership in the Society:

William P. Bobbs, 431 Melrose Ave., Toronto 12
Gordon Burlton, 12 Alpha Ave., Toronto 5
A. Davy Brown, B.A., 18 Mann Ave., Toronto 12
David M. Cockfield, 29 Biggar Ave., Toronto 10
Gordon E. Gutsell, 540 Charlotte St., Peterborough
Basil V. Kerr, 759 Kingston Rd., Toronto 8
Robert G. Lynn, 11 Laxton Ave., Toronto 3
William N. Pursel, 939 Main St. N., Weston, Toronto 15
Frederick Rance, Richmond Hill, Ont.
Peter Sakowski, 116 Regent St., Toronto 9
Russell L. Sutherland, 106 Gates Ave., Toronto 8

There were four people nominated, but since there would be no opportunity to present these candidates for election at the next meeting with the Royal Canadian Institute, it was moved by Miss Creeper and seconded by Miss Northcott that By-Law 2 be suspended and these candidates also be elected. These were:

Kenworth E. Macfarlane, 86 Royal York Rd. S., Toronto 18
Carl L. Mills, 1 Ascot Rd., Havilland P.O., Ont.
Ernest T. Watts, 51 Simpson Ave., Toronto 6
William T. Tutte, Dept. of Mathematics, U. of T., Toronto 5

The feature of this Members' Night was the David Dunlap Observatory Players, under the direction of Dr. J. F. Heard. The subject was Galileo. As an introduction, Dr. H. S. Hogg commented on the two rival views of Aristotle and Copernicus. It was in 1543 that Copernicus presented his new theory of a revolving and rotating earth that did away with the complex deferents and epicycles of the Ancients. There was no observational proof for the Copernican theory for another fifty years. In 1572 Tycho Brahe's nova exerted a sudden influence on the current ideas; it disproved Aristotle's theory that nothing changes in the heavens, and yet why did this bright object not reflect the motion of the earth if Copernicus was right? It was interesting to learn that an Englishman translated the book of Copernicus into English and it seems to have been widely read there. His name was Thomas Digges, and he also seems to have known how to place lenses to obtain magnification.

After Dr. Hogg had set the background, Mr. Baglow gave readings from *The Sidereal Messenger*, the book in which Galileo set forth the substance of his first observations with his telescope, and the suggestion that the moons of Jupiter were direct proof of the correctness of the Copernican theory. This book came under the prohibition of the Pope, but Galileo did not take it too seriously. He determined to drive home his argument in another book, the famous *Dialogues*. Parts of this book were then read by the D.D.O. Players with Dr. Heard as Commentator, Dr. Williamson as Salviati (the pro-Copernican), Mr. Baglow as Sagredo (the neutral party), and Mr. Rodgers as Simplicio (the Aristotelian).

Mrs. Hogg then gave a brief account of the asteroid Vesta, the brightest of them all, which is in opposition on Saturday, March 1, and readily visible in opera glasses.

March 8, 1952—The meeting was held in Convocation Hall and was a joint meeting of the Royal Canadian Institute and the Royal Astronomical Society of Canada. Mr. J. S. Dickson, President of the Royal Canadian Institute, was in the chair.

Mr. Dickson introduced the speaker, Dr. P. M. Millman, Chief of the Stellar Physics division of the Dominion Observatory, Ottawa. His subject was "Visitors from Space."

Dr. Millman opened his talk by describing three meteors which are known to have hit the earth. The first was in 1949 when a New Brunswick family were startled to hear a sound like a low flying aircraft, and then to see a dark smoking rock fall on their farm. The second case was similar to the first, and occurred at Dresden, Ontario, in 1939. The last story was about the most famous of meteors, the one that created the vast crater in Arizona. Dr. Millman had three samples of these meteorites on display, one which showed evidence of once having been part of the outer crust of a large planet, the second from half-way down, and the third from the core.

Fireballs are a bright variety of meteors, occuring low in the earth's atmosphere, and may be bright enough to be seen in daylight. One of this nature was seen in the Montreal-Ottawa region on November 2, 1950. Another spectacular sight is a meteor shower, such as the very spectacular one on October 9, 1946. In a shower, the meteors seem to radiate from one point in the sky, and this Dr. Millman demonstrated very effectively on the screen.

Meteor shower orbits are much more elliptical and have a greater inclination to the plane of the ecliptic than do the fireball orbits. The meteor shower orbits are more like those of comets, while the fireball orbits resemble those of the asteroids.

Meteors travel through the atmosphere at different speeds. The faster meteors have ionized constituents while the slower ones have atoms in their normal state. Dr. Millman then showed slides illustrating the passage of a meteor through the atmosphere. The kinetic energy is transferred into heat and light and the production of charged particles. It is these charged particles that reflect radio waves, and make it possible to watch meteors by radar.

There have also been found very small dust particles coming from outside the earth's atmosphere. These are called micro-meteors. This has been evidenced in the zodiacal light, from V_2 rockets whose noses have been pitted with these micro-meteorites, and by the frequency received from microphones in these rockets. By examining sea bottoms the amount that has fallen can be found, and the results seem to agree with the amount that is falling every day—about 2000 tons of matter.

The speaker was thanked by Dr. H. S. Hogg, and the meeting was then adjourned.

March 25, 1952—The March Members' Night meeting was held in the McLennan Physics Laboratory. The President, Mr. F. L. Troyer, was in the chair.

Miss R. J. Northcott and Miss B. R. Creeper discussed the material in the OBSERVER'S HANDBOOK for 1952. Miss Northcott explained the aspects and abbreviations, astronomical phenomena, and the solar system, while Miss Creeper talked about occultations, meteor showers, and variable and double stars.

Following this discussion there were shown five films. The first three, "The Solar Family," "The Moon," and "The Story of the Telescope" need no description. The fourth, "Hermits of the Sky," was a most interesting picture concerning the life of astronomers at Pic du Midi in France. The picture was taken high up in the mountains at an observatory which is accessible only three months a year. The scenic qualities of the picture were as impressive as the astronomical. The last picture, "Exploring Space," was a rocket ship story, and left much to be desired from a strictly astronomical point of view.

BARBARA CREEPER, *Recorder.*

VANCOUVER CENTRE

Honorary President—G. M. Shrum, Ph.D.
President—Carl Jorgenson*
Vice-President—A. Outram
Treasurer—C. A. Rogers
Secretary—R. J. Clark, Ph.D., 1988 Western Parkway, Vancouver 8.
Recorder—J. S. Laurie
Public Relations—Eileen Laurie
Council—A. M. Crooker, Ph.D.; C. W. Deans; Dean W. H. Gage; Capt. C. A. McDonald; E. M. Price; T. Spence.

*Deceased

EDMONTON CENTRE

Honorary President—J. W. Campbell, Ph.D.
President—E. Phibbs
Vice-President—H. M. Burt
Treasurer—H. J. Montgomery
Secretary—E. H. Gowan, Ph.D., University of Alberta, Edmonton.
Librarian—E. S. Keeping (*Acting Secretary*)
Assistant Librarians—Miss E. Valens; Mrs. E. Siemens
Council—S. G. Deane; H. Grayson-Smith, Ph.D.,; R. F. Mainwood; W. R. Mjolaness; A. D. Turner.
Social Hostesses—Miss E. Kennedy; Mrs. S. F. Page; Mrs. R. N. Shaw.

QUEBEC CENTRE

Patron—Mgr. Ferdinand Vandry, P.A., V.G.
Président—Albert Duberger
1er Vice-Président—Albert Duberger
2e Vice-Président—l'abbé Rosario Benoit
Secrétaire-Trésorier—Paul-H. Nadeau, 275 rue Saint-Cyrille, Québec.
Secrétaire-adjoint—Jacques Sauvé
Assistant-secrétaire—Mlle. Louise Lachance
Conseil—Jean-Pierre Bernier; Alfred Dumont; G. F. Gibsone; Gerard Lafontaine; David I. McGill; Lionel-Pierre Peloquin; Bernard Piche; Emelien Pouliot; Oscar Villeneuve; et *les anciens Présidents*—Geo.-E. Gagne; Jean-Chs. Magnan; Lucien Pouliot.

WINDSOR CENTRE

Honorary President—His Honour J. J. Coughlin, B.A.
President—Russell Warwick, B.A.
Vice-President—Henry Lee, B.S.E.E.
Librarian—Daniel C. Bawtenheimer
Secretary—Robt. C. Bradley, M.A., 3774 Montcalm St., Windsor.
Treasurer—William J. Person, L.I.A.
Council—Hugh S. Cunningham, B.A.; Cyril Hallam, B.A.; Almon Hare, B.A.; Percy C. Hawkes; Edward M. Kreeser, B.Sc.; William G. Mitchell, B.A.I.; Cameron Montrose, B.A.; Lorne R. Rogers, B.A.; Constantine Russel; E. H. Thistlethwaite.

SASKATOON CENTRE

GUELPH CENTRE

CENTRE FRANCAIS DE MONTREAL

Président—De Lisle Garneau
Vice-Président—W. Grignon
Bibliothécaire—J. E. Guimont
Rapporteur—Jean Asselin
Secrétaire-Trésorier—Mlle. Fleurange Laforest, 3445 Papineau St., appt. 2, Montreal.
Directeur des observations—Jean Naubert
Directeurs—Roger Bonin; J. A. Buteau; H. Colette; P. E. Fontaine; Mlle. Marcelle Gauvreau; J. Leduc; Mlle. Georgette Lemoyne; Rev. Fr. Robert, f.e.c.; M. Seguin.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XLVI, NO. 4 JULY-AUGUST, 1952 WHOLE NO. 397

PAGE

Articles

The Joint American Astronomical Society–Astronomical Society of the Pacific Meeting at Victoria, B.C., June 25–28, 1952 ..... *R. M. Petrie* 129

Celestial Emission-line Objects of Early Type *C. S. Beals* and *J. A. Rottenberg* 133

The Frequency and Characteristics of Binary Systems among Bright-line B-type Stars ..... *R. F. Rodgers* 147

Variable Star Notes ..... *Margaret W. Mayall* 151

Meteor News

Montreal Perseid Observations ..... *Peter M. Millman* 155

Out of Old Books

The Introduction of the Copernican System to England: II. John Dee and the Circle at Mortlake ..... *Helen Sawyer Hogg* 158

Notes and Queries

The Date of Stonehenge (*R.L.B.*); Telescopes in South Africa (*C.A.C.*); Crater Elegante (*R.J.N.*); Planetensektion der Sternfreunde, Germany (*Gunther Roth*); Centenary of Laval University (*R.J.N.*); J. W. Stein, S.J. (*J.F.H.*) 165

Review of Publications

Physique de la Planète Mars by Gerard de Vaucouleurs (*J.F.H.*); L'étude optique de l'atmosphère terrestre by various authors (*J.F.H.*); The Astronomical Universe by Wasley S. Krogdahl (*H.S.H.*); Regelmaat en Wisseling bij Zonsverduisteringen by Prof. G. van den Bergh (*R. F. Rodgers*) 169

Meetings of the Society

At London–At Toronto 172

Address of Editors: David Dunlap Observatory, Richmond Hill, Ont.

Business correspondence and remittances should be addressed to J. H. Horning, Treasurer of the Society, 3 Willcocks St. Toronto.
$3.00 per annum, Single number, 50 cents.
Subscription to the JOURNAL is included in membership fee.

PRINTED IN CANADA

WILDSIDE

X